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Research Document 2009/063

Document de recherche 2009/063

Long-term variability in phytoplankton and zooplankton abundance in the Northwest Atlantic in Continuous Plankton Recorder (CPR) samples

Variabilité à long terme de l'abondance de phytoplancton et de zooplancton dans l'Atlantique Nord-Ouest selon les échantillons de l'enregistreur continu du plancton (CPR)

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

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Correct citation for this publication:
La présente publication doit être citée comme suit :

Head, E., and P. Pepin. 2009. Long-term variability in phytoplankton and zooplankton abundance in the Northwest Atlantic in Continuous Plankton Recorder (CPR) samples. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/063. vi + 29 p.

ABSTRACT

A new way to present Continuous Plankton Recorder (CPR) data collected in the Northwest (NW) Atlantic for reporting to the Atlantic Zone Monitoring Programme (AZMP) has been developed. Data for 12 standard CPR taxa from 8 standard regions, 4 on the Canadian continental shelf (the CPR E line) and 4 extending eastward beyond it to Iceland (the CPR Z line) are included. The reporting consists of time series of standardised annual abundance anomalies and seasonal cycles for 5 sequential multi-year periods between the 1960s and 2006. For the years prior to the 1990s, only decadal annual averages are reported for the 1960s to the 1980s, because there were numerous, sometimes prolonged, interruptions in CPR sampling during those decades. Results for the 4 regions covering the Scotian and Newfoundland shelves show that phytoplankton levels were higher in the 1990s and 2000s than in previous decades, *Calanus finmarchicus* levels decreased in the 1990s, but made a come-back on the Scotian Shelf in the 2000s (although not on the Newfoundland Shelf), 2 arctic *Calanus* species increased in abundance in the 1990s and stayed high in the 2000s, while euphausiid levels decreased and remained low over the same time periods. On the Scotian Shelf, the phytoplankton bloom started earlier and young stage *Calanus* appeared earlier in the year after 1992. In the deep ocean, changes in abundance were not as dramatic as on the shelf, although phytoplankton, small copepods and forams increased in abundance in the mid-2000s, possibly as a result of increased temperatures. Also, seasonal cycles beyond the shelf did not change over the decades.

In 2007, the latest year for which data were available, sampling was only possible from January to May so that annual average abundance values could not be calculated. Instead, values are reported for each month that was sampled and these are compared with multi-year monthly averages representative of earlier sampling periods, *i.e.* with the multi-year seasonal cycles. There were no dramatic changes in shelf or open ocean regions in 2007.

RÉSUMÉ

Une nouvelle façon de présenter les données recueillies dans l'Atlantique Nord-Ouest pour la préparation du rapport du Programme de monitorage de la zone Atlantique (PMZA) a été mise au point pour le programme d'enregistrement continu des données sur le plancton (CPR). Les données pour 12 taxons standard du CPR de 8 régions, soit 4 sur le plateau continental du Canada (la ligne E du CPR) et 4 s'étendant plus loin à l'est vers l'Islande (la ligne Z du CPR) sont incluses. Le rapport consiste en des séries chronologiques d'anomalies d'abondance annuelle et de cycles saisonniers normalisées pour 5 périodes pluriannuelles séquentielles entre les années 1960 et 2006. Pour les années antérieures aux années 1990, seules les moyennes annuelles décennales sont rapportées des années 1960 aux années 1980, car il y a eu de nombreuses interruptions, parfois prolongées, pour l'échantillonnage du CPR pendant ces décennies. Les résultats pour les 4 régions s'étendant sur les plateaux néo-écossais et de Terre-Neuve indiquent que les niveaux de phytoplancton étaient plus élevés dans les années 1990 et 2000 que lors des décennies précédentes, que les niveaux de *Calanus finmarchicus* ont diminué dans les années 1990, mais ont remonté sur le Plateau néo-écossais dans les années 2000 (sauf sur le plateau continental de Terre-Neuve), que 2 espèces de *Calanus* arctique ont augmenté en abondance dans les années 1990 et sont restées à un niveau élevé dans les années 2000, tandis que les niveaux d'euphausaciés ont diminué et sont restés bas pendant les mêmes périodes. Sur le plateau néo-écossais, la prolifération de phytoplancton a commencé plus tôt et celle du *Calanus* aux premiers stades est apparue plus tôt, dans l'année après 1992. En eau profonde, les changements d'abondance n'ont pas été aussi importants que sur le Plateau, même si l'abondance de phytoplancton, de petits copépodes et de foraminifères, a augmenté au milieu des années 2000, possiblement en raison de l'augmentation de température. En outre, les cycles saisonniers au-delà du Plateau n'ont pas changé au courant des décennies.

En 2007, soit la dernière année pour laquelle des données sont disponibles, l'échantillonnage n'a été possible que de janvier à mai, de sorte que les valeurs d'abondance annuelle moyenne n'ont pas pu être calculées. On indique plutôt les valeurs pour chaque mois au cours duquel on a pu faire un échantillonnage et celles-ci sont comparées avec les moyennes mensuelles pluriannuelles représentatives des périodes d'échantillonnage antérieures, c.-à-d. avec les cycles saisonniers pluriannuels. Il n'y a pas eu de changements importants pour les régions du plateau ou du grand large en 2007.

INTRODUCTION

Continuous Plankton Recorder (CPR) sample collections in the Northwest (NW) Atlantic have been mainly along a track from Reykjavik (Iceland) to St. John's, Newfoundland (the Z line), and between St. John's and the New England Coast, along the Scotian Shelf (the E line). The first samples were collected in the Irminger Sea in 1957, and sampling was extended farther west to the Scotian Shelf a few years later. Sampling has continued to the present with some interruptions: there was no sampling west of 45°W on the Canadian continental shelf between 1977 and 1990, and no sampling anywhere on either line between 1987 and 1990. In addition, while sampling is supposed to be once a month year round, before 1992 monthly coverage varied for different regions of the E and Z lines. In the analysis presented here, because of the inconsistencies in sampling frequency in the decades prior to the 1990s, no annual average abundance values have been calculated for individual years prior to 1992, but instead decadal averages have been generated by averaging the decadal average monthly means. Also, in 2007, sampling was only possible from January to May, because the vessel that had been towing the CPRs was sold to a new company, which was unwilling to continue to provide the service: sampling only resumed in June 2008. Thus, no annual average abundance values could be calculated for 2007, although values are reported for each sampling month and compared with multi-year monthly averages representative of earlier sampling periods.

In this report, unlike previous annual contributions of CPR data to previous Atlantic Zone Monitoring Program (AZMP) reports, which only presented results for the Scotian and Newfoundland shelves, data from beyond the Canadian continental shelf, between longitudes 45 and 25°W is also shown. This is in response to the needs of the science programme component of the Department of Fisheries and Oceans (DFO) International Governance Strategy (Theme: Ocean Variability and Marine Ecosystems). This and future annual reports of CPR data will provide an understanding of the marine ecosystems beyond the Canadian continental shelf, of its variability on an inter-annual basis and of its response to climate change (*i.e.* global warming) over the long-term.

The CPR categories to be included in this and future reports will be consistent for all regions and will include indices of phytoplankton abundance (diatoms, dinoflagellates and the phytoplankton colour index), indices of the abundance of the young and late stages of the dominant zooplankton species (*Calanus finmarchicus*), indices of two arctic *Calanus* species, and groups of other small and large zooplankton forms. As well, in response to concerns about the effect of ocean acidification, due to increased carbon dioxide uptake in the NW Atlantic, data for a previously unreported category, *Limacina*, a genus of pteropod susceptible to ocean acidification, will also be included in this and future reports.

METHODS

Continuous Plankton Recorder Sampling

The CPR survey[1] provides an assessment of long-term changes in abundance and geographic distribution of planktonic organisms ranging from phytoplankton to the young stages of larger macrozooplankon (Warner and Hays 1994, Richardson et al. 2006). CPRs are towed by ship of opportunity along a number of standard routes and collect plankton at a nominal depth of 7 m. Water passes through a small aperture in the front of the CPR and is filtered through a filtering

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[1] See the SAHFOS (Sir Alister Hardy Foundation for Ocean Science) web site (http://192.171.163.165/) for a description of the CPR survey programme

silk (gauze), which is pressed against a second silk and wound on to a drum in a chamber containing preservative within the instrument. Sections of silk representing 18.5 km tow distance and about 3 m^3 of water filtered are analysed microscopically using standard methods, which have not changed since the inception of the survey. Because of the time it takes to analyse the samples, data are not available until 1 year after the sampling year, *i.e.* in early 2008, the most recent data available are from 2007.

Analysis of Continuous Plankton Recorder Data

Over the years, the ships' tracks have varied somewhat and the samples that contributed to the analysis presented here are shown in Fig. 1. Data from the slope waters south of the Scotian Shelf and South Newfoundland Shelf (SNL) were excluded, as were data from north of 50°N between longitudes 45 and 53°W in the Newfoundland Shelf (NLS) region. The Western Scotian Shelf (WSS) included data from between longitudes 62 and 66°W, the Eastern Scotian Shelf (ESS), data from between longitudes 57 and 62°W, and the South Newfoundland Shelf, data from between longitudes 53 and 57°W. East of 45°W, data were averaged over 5° longitude sections to examine spatial differences in the abundance of plankton categories.

The plankton analysts at SAHFOS identify and count >400 taxonomic groups for samples collected throughout the North Atlantic. Some new taxa have been added to the list of analysed groups over the years (Richardson et al. 2006), but all of the groups shown in this analysis, with the exception of copepod nauplii, have been identified and enumerated since the late 1950s. Data for 12 taxonomic groups are included in this report:

- Diatoms – is the sum of abundances of all diatom species that are identified and enumerated.
- Dinoflagellates – is the sum of abundances of all dinoflagellate species that are identified and enumerated.
- Phytoplankton colour index (PCI) – is the intensity of greenness of the gauze when first removed from the CPR, as compared to a standard colour chart.
- *Calanus* I-IV – is the sum of abundances of all young stage (I-IV) *Calanus* and is dominated by young stage *Calanus finmarchicus.*
- *Calanus finmarchicus* V-VI – is the sum of abundances of late stage (V and VI) *Calanus finmarchicus.*
- *Calanus glacialis* – is the sum of abundances of late stage (V and VI) *Calanus glacialis.*
- *Calanus hyperboreus* – is the sum of abundances of stages III, IV, V and VI *Calanus hyperboreus.*
- *Paracalanus/Pseudocalanus* – is the sum of abundances of young stage *Paracalanus*, *Pseudocalanus* and any other small copepods that cannot be readily identified.
- Formanifera (Forams) – is the sum of abundances of all species. This category has only been enumerated since 1992.
- Euphausiids – is the sum of abundances of all euphausiid species and stages.
- Hyperiids – is the sum of abundances of all hyperiid amphipod species and stages.
- *Limacina* – is the sum of abundances of all organisms from the genus *Limacina.*

The abundance data from all of the groups, except the PCI, were log(N+1) transformed prior to averaging and statistical analysis. Data for individual taxonomic groups were averaged first over samples collected within a given area and within the same sampling month and year. These averages were then averaged over each month sampled within each sampled "decade" to give regional decadal monthly averages. The term decade is used loosely here: the 1960s decade includes any data collected prior to 1960 plus any data collected between 1960 and 1969, the

1970s decade includes any data collected between 1970 and 1979 (or between 1970 and 1976 in some regions), the 1980s decade includes any data collected between 1980 and 1986, the 1990s includes any data collected between 1991 and 1999 and the 2000s includes data collected between 2000 and 2006.

For the decades prior to the 1990s, regional decadal monthly averages were averaged over the 12 months of the year to give decadal annual averages: these values are used to represent annual abundances for these decades. The same calculation was made for the 1990s, and these decadal annual averages were used to represent the annual averages for 1990 and 1991; years in which the number of missing months was too large to allow calculation of annual averages. For 1992 to 2006, annual average abundance estimates were calculated for each individual year from the monthly average abundances. In years where one month or two sequential months were missing in a region, linear interpolation was used to fill in the missing months. If there were three or more sequential months missing, or if there were more than four months missing throughout the year, no annual average was calculated for that year for that region.

Long-term mean abundances were calculated over all years for each region, using the same value for each year for the decades prior to the 1990s, using the 1990s decadal average for 1990 and 1991 and using the values for individual years from 1992 to 2006. Annual (or decadal) standardised abundance anomalies were derived from these by subtracting the long-term average from the values for each individual year and by dividing by the standard deviation of the long-term average.

Analysis of Sea Surface Temperature (SST) Data

Seasonal cycles of sea surface temperature and chlorophyll concentration were derived using a combination of Reynolds/NCEP data (from http://poet.jpl.nasa.gov/), which combines *in situ* and AVHR satellite observations for temperature. Areas representative of the CPR sampling regions were defined by the longitudinal and latitudinal limits of the sampling locations within each region as seen in Fig. 1. The data are collected on a weekly basis, and were averaged first to give monthly means for each year and then to give annual averages. These data are only available since 1982. The standardised anomalies were calculated for each region relative to the mean values over the entire time series.

RESULTS AND DISCUSSION

This report presents the CPR data in a new format and offers a comparison of trends in plankton abundance over several decades and a larger spatial scale than has been previously reported. As yet, no detailed analysis has been performed on the data, so that here only a few of the outstanding points are discussed.

Long-term Changes in Annual Sea Surface Temperatures (SSTs)

In this analysis, it was judged appropriate to use comparable datasets for all regions of the E and Z lines, and to concentrate on near surface data, because the CPR samples at 7 m. For this reason, data from the NASA Jet Propulsion Laboratory website (see Methods) were used, which combine satellite and *in situ* data. The database only starts in 1982, so that the time series presented here starts then as well.

The highest long-term SST was recorded on the Western Scotian Shelf and the lowest in the Newfoundland Shelf regions (Fig. 2). Compared with the long-term average, SSTs were warm in continental shelf regions (west of 45°W) in 1983 and1984, cool through the late 1980s and early 1990s, extremely warm in 1999 and 2000 and again in 2006. In the deep ocean east of 45°W, SSTs were generally cooler than average throughout the 1980s and early 1990s, and warmer than average after 1996, with especially warm conditions in 1998, 2005 and 2006.

Long-term Changes in Annual Abundance of Plankton

1. Phytoplankton

Long-term average values for diatom and dinoflagellate abundance and the phytoplankton colour index were generally higher on the continental shelf (*i.e.* west of 45°N) than farther east in the deep ocean (Fig. 3). Diatom abundance and PCI had maximum values on the Newfoundland Shelf, while dinoflagellate abundance was highest in the South Newfoundland Shelf.

Since 1990, all three indices of phytoplankton abundance have generally been above the long-term average on the continental shelf. The same is also true for the PCI farther east in the deep ocean, although here diatom and dinoflagellate abundance remained relatively low in the early 1990s and increased thereafter. All three indices showed strong positive anomalies in the deep ocean in 2005-2006, perhaps related to the higher than normal SSTs (Fig. 2). On the Scotian Shelf, all three have decreased since their high values in the late 1990s and early 1999, while on the Newfoundland Shelf, dinoflagellate abundance was at an all time high in 2006, whereas diatom abundance and the PCI peaked in 2001-2002 and the mid-1990s, respectively.

2. *Calanus finmarchicus*

The long-term average abundance of the two CPR categories that account for *Calanus finmarchicus* (young or late stages) both showed maximum values in the Newfoundland Shelf region, with long-term average abundances for the young stages (*Calanus* I-IV) slightly above average on the Scotian Shelf, and late stages somewhat above average in the deep ocean between 45 and 35°W (Fig. 4).

Overall, the patterns of abundance of young stage *Calanus finmarchicus* on the continental shelf indicate relatively high values in the 1960s or 1970s, followed by relatively low values in the 1990s, and a return to relatively high values on the Scotian Shelf since 2004, although this latter increase was not seen on the Newfoundland Shelf (Fig. 4). The patterns are similar for late stage *C. finmarchicus* abundances on the shelf, except that in this case the recovery from low values in the 1990s began at the beginning of the 2000s, and again there has been little sign of recovery on the Newfoundland Shelf.

East of 45°W, in the deep ocean, the abundance of *Calanus* I-IV was generally low in the 1960s to 1980s, with higher values since the early 1990s and especially high values after 2003. The increase in the later years may be related increasing temperatures (Fig. 2). The abundance of late stages between 40 and 45°W was high in the 1960s, somewhat higher during the 1990s, and low after 2003. Farther east the abundance of late stage *C. finmarchicus* was generally below the long-term average throughout the 1960s, 1970s and 1980s and quite variable thereafter. Levels were relatively high in three of the last four years of the time series (*i.e.* 2003, 2005 and 2006).

3. Arctic species - *Calanus glacialis* and *Calanus hyperboreus*

Long-term average abundances of these species are generally very low and variable (Fig. 5), showing maximum values on the Newfoundland Shelf and either the Scotian Shelf (*C. glacialis*) or in the deep water to the east of the Newfoundland Shelf (*C. hyperboreus*, 40-45°W). These distributions reflect the origins and depth preferences of the species. Thus, both are most abundant over the Newfoundland Shelf, the area most influenced by outflow from the Arctic, which is reflected in the region's low SST (Fig. 2). *Calanus hyperboreus* is a deep water species, so that it is also relatively abundant just beyond the Newfoundland Shelf (40-45°W region), an area also influenced by flow from the north (Fig. 5). In addition, it is also resident and abundant in the Gulf of St. Lawrence, which is the source for the Scotian Shelf (Head et al. 1999). By contrast, *Calanus glacialis* is a shelf species, which is more abundant in shelf regions than *C. hyperboreus*. It is not very abundant in the Gulf of St. Lawrence, which is, nevertheless, probably the source for the Scotian Shelf. Differences in abundance in CPR samples may also relate to differences in vertical distributions of the two species. *C. hyperboreus* is a larger species than *C. glacialis*, and more vulnerable to visual predation. Thus, a greater proportion of the population may generally reside deeper in the water column, where it is not accessible to CPR sampling.

On the continental shelf, both species were more abundant in the 1990s and/or 2000s than in previous decades, with some evidence of a progression down the shelf over time, so that values increased earlier in the two regions of the Newfoundland Shelf than on the Scotian Shelf.

4. Small copepods and foramnifera

The CPR taxon "*Paracalanus/Pseudocalanus*" includes not only these genera, but also small copepods that cannot easily be identified as belonging to any other taxon. Thus, the group is a general index for small copepods. Long-term mean abundances are generally higher on the continental shelf, *i.e.* west of 45°W (Fig. 7). By contrast, the average long-term abundance of forams, for which only data since 1992 were available, is greater in the deep ocean east of 45°W than in shelf regions.

On the continental shelf, the general pattern is that small copepods were mainly slightly more abundant than the long-term mean in the 1960s, decreasing in the 1970s, increasing in the 1990s and decreasing again in the 2000s. This pattern is clearest on the Eastern Scotian Shelf, although here, and elsewhere, there was generally a high degree of inter-annual variability in the 1990s and 2000s. On the Newfoundland Shelf, the abundance of small copepods remained relatively high through the 1990s and 2000s, and there is some indication of an inverse relation between the abundance of small copepods and that of *Calanus* I-IV both here and on the Scotian Shelf.

To the east of 45°W, beyond the continental shelf, abundances of small copepods were below the long-term average throughout the 1960s, 1970s and 1980s. Levels increased in the late 1990s, decreased somewhat between 2000 and 2002 and then increased again. The abundance of forams in the deep ocean showed a similar trend and it seems possible that recent increases were related to increasing SSTs (Fig. 2), as has also been suggested for *Calanus* I-IV (see above).

5. Euphausiids and hyperiid amphipods

The small size of the orifice through which water flows into the CPR precludes the capture of adult euphausiids and amphipods, but their young stages are small enough to be caught and likely represent an index of abundance for each of these groups. Both show maximum values for their long-term average abundances in the 40-45°W region, just east of the continental shelf, and both show relatively low long-term abundances south of Newfoundland and on the Eastern Scotian Shelf (Fig. 7).

On the continental shelf (west of 45°W), euphausiid abundances were highest in the 1970s and have generally been well below their long-term average values since the early 1990s. Farther east, in the 40-45°W region, euphausiid abundances were above the long-term mean in the 1960s, decreasing in the 1970s and 1980s, increasing somewhat in the early 1990s and decreasing again in the 2000s. East of 40°W, abundances were lower or close to the long-term average in the 1960s to the 1980s, relatively high in the early 1990s and variable thereafter.

Abundances of hyperiids in all regions were generally lower than, or close to, their long-term average values in the 1960s to the 1980s, and in all regions there was a general increase in abundance in the 1990s, especially on the South Newfoundland Shelf and in the 35-40°W regions. Since 2000, abundances have increased further in the 30-35°W regions and decreased on the Newfoundland Shelf. Elsewhere, they have been variable, but were generally higher than in the 1960s to 1980s.

6. *Limacina*

Limacina has been chosen to monitor long-term changes in the abundance of organisms that are susceptible to ocean acidification because it has been identified and counted since the early 1960s and because it is relatively abundant and widely distributed in the NW Atlantic.

The CPR taxon *Limacina* includes individuals of all of the *Limacina* species that are found in the North Atlantic. These organisms have an external shell, which resembles a snail's shell, composed of aragonite, a form of calcium carbonate that is susceptible to dissolution at low pH (*i.e.* under acid conditions). It has been suggested that under a "business as usual" scenario for future emissions of anthropogenic CO_2, this genus could be adversely affected by 2050 (Orr et al. 2005). Monitoring their abundance in the NW Atlantic will show when this does start to happen. Long-term average abundances indicate that along the E and Z lines the genus is most abundant in the 40-45°W region and on the Western Scotian Shelf (Fig. 8).

In the 1990s and 2000s, the annual abundance of *Limacina* tended to be quite variable on the Scotian Shelf and on the South Newfoundland Shelf. On the Western Scotian Shelf, *Limacina* abundance was unusually high in 1994, 1999 and 2000, but it has been lower than the long-term average since 2001. *Limacina* abundance has also been relatively low since 2001 on the Eastern Scotian Shelf, but here the year of maximum abundance was 1992. On the Newfoundland Shelf, *Limacina* abundance was relatively low in the 1960s and 1970s, but relatively high throughout the 1990s, lower in the early 2000s and high in 2005 and 2006. This same pattern was observed farther east in the 40-45°W and 35-40°W regions.

Decadal Changes in Seasonal Cycles of Phytoplankton Abundance on the Continental Shelf, with January to May Values for 2007

1. Phytoplankton

On the Scotian Shelf, both diatom abundance and the phytoplankton colour index showed increases in the winter months (January-March) in the 1990s and 2000s compared with earlier decades, although the peaks have generally been in April in all decades (Fig. 9). In 2007, diatom abundance was also high in the winter months, whereas the PCI seemed to have decreased, especially on the Eastern Scotian Shelf. Dinoflagellate abundance on the Scotian Shelf shows no obvious seasonal peak, with values higher in the April–June period in the 1990s and 2000s. In 2007, dinoflagellate abundance during the early part of the year was lower than in the 1990s and early 2000s, returning to levels seen in the 1960s and 1970s.

Farther east on the South Newfoundland and Newfoundland shelves, the PCI was higher in the 1990s and 2000s than in previous decades from November to June, as were abundances of dinoflagellates, while the abundance of diatoms showed slightly higher values in these later decades only on the Newfoundland Shelf only in March and April. The peak in diatom and PCI abundance was generally in April, as on the Scotian Shelf. Abundances of diatoms and dinoflagellate and the PCI in 2007 seemed to be more consistent with those of the 1990s and 2000s than with those of earlier decades.

Beyond the continental shelf, east of 45°W, but west of 30°W, the seasonal peaks in diatom abundance occur later than on the shelf, in June, and there is a distinct recurrent second peak in September in the 30-35°W region (Fig.10). East of 30°W diatom abundance increases rapidly between April and May, remaining high until August. There have been no obvious changes in seasonal cycles of diatom abundance over the decades and monthly values in 2007 were consistent with average values for the early 2000s. The abundance of dinoflagellates was higher in summer in the 2000s compared with previous decades between 30 and 45°W, but values between January and May were always low, as was seen in 2007. The PCI showed inconsistent changes in its seasonal cycle among decades and regions, with monthly values in 2007 lower than those of the early 2000s and similar to those of previous decades.

2. *Calanus finmarchicus*

On the Scotian Shelf, the peak in young stage abundance (*Calanus* I-IV) has occurred earlier in the year since the 1990s, which may be linked to the fact that high phytoplankton concentrations are also found earlier in the year (see above and Head and Pepin 2008). On the Newfoundland Shelf, at Station 27, higher temperatures and earlier blooms tend to co-occur and to lead to earlier the appearance of young stage *C. finmarchicus* (Head et al. 2009). In the CPR data, however, there is little sign that the higher temperatures of the 2000s, relative to the 1990s, led to an earlier occurrence of the peak of young stages (Figs. 8 and 11), although the low sampling frequency and year-to-year changes in sampling dates may preclude the resolution necessary to observe such an effect. Monthly values for *Calanus* I-IV abundance in 2007 were generally similar to those of the 1990s and 2000s, with one exceptionally high value in June on the South Newfoundland Shelf.

Seasonal cycles of late stage *C. finmarchicus* abundance do not show obvious seasonal cycles on the Scotian Shelf or the Newfoundland Shelf, nor were there any obvious decadal changes in them. There is a peak in abundance on the South Newfoundland Shelf between about November and March, which has been consistent throughout the decades. Monthly values for

C. finmarchicus V-VI abundance in 2007 were consistent with those of previous decades, with one exceptionally high value in June on the South Newfoundland Shelf.

East of 45°W in the deep ocean, seasonal cycles of both *Calanus* I-IV and *C. finmarchicus* V-VI have been remarkably consistent among the decades, with peaks in the abundance of the former in June or July and broad peaks in abundance of the latter from April to October between 35 and 45°W and with two distinct peaks centred on May-June and September east of 35°W (Fig. 12). Monthly values in 2007 were consistent with those of previous decades.

3. *Calanus glacialis* and *Calanus hyperboreus*

Calanus glacialis and *Calanus hyperboreus* are only present in CPR samples for a few months of the year both on and beyond the continental shelf (Figs. 13 and 14). *C. glacialis* is present for more months than *C. hyperboreus* and generally in the first half of the year. *C. hyperboreus* is generally present only in April and/or May. Monthly abundances of *C. glacialis* were higher in the 1990s and/or the 2000s than in prior decades and in 2007 values were similar to the high these high values on the shelf and as far east as 35°W, with expected near zero values farther east. *C. hyperboreus* abundance showed similar patterns among the decades, but in 2007 abundance remained high on the shelf, whereas the species was not observed farther east.

3. Small copepods and foramnifera

The abundance of small copepods on the Scotian Shelf has been relatively low in winter (January-March) throughout the decades, but otherwise the seasonal cycle shows no obvious pattern (Fig. 15). For the two Newfoundland Shelf regions, the abundance of small copepods has shown a more pronounced seasonal cycle since the 1990s, with a broad peak from fall to spring and lower values in summer. Monthly values in 2007 are not inconsistent with those of previous decades. East of 45°W seasonal cycles of abundance for small copepods have generally shown peaks in summer and/or fall, with especially high values west of 40°W in the 2000s (Fig. 16). Monthly values in 2007 were similar to the high values of the 2000s west of 35°W in June, but there were no samples in May or June from farther east.

For both the 1990s and early 2000s, abundances of foramnifera on the Scotian Shelf were highest during the fall and the same was true for the South Newfoundland Shelf (Fig. 15). On the Newfoundland Shelf, the abundance of forams shows no obvious seasonal cycle. Monthly values in 2007 were relatively high on the Newfoundland Shelf, but sampling did not cover the part of the year where high numbers were expected on the Scotian and South Newfoundland shelves. East of 45°W, there is a broad peak in the abundance of forams between 40 and 45°W from April to October, while farther east this peak stretches from June to October (Fig. 16). In 2007, monthly values for the abundance forams in the 40-45°W regions were similar to those of the 1990s and 2000s and farther east values were low, as expected from the seasonal cycles of previous periods.

4. Euphausiids and hyperiid amphipods

On the Scotian Shelf, euphausiid abundances were highest during summer and fall in the 1960s and 1970s, whereas in the 1990s and 2000s the summer high values decreased, so that the seasonal abundance peak shifted to later in the year (Fig. 17). In 2007, the sampling months were not during the peak, but values were consistent with those of previous decades. In the two Newfoundland Shelf regions, seasonal cycles were not as well defined and again monthly values in 2007 were not inconsistent with values from previous decades. East of 45°W, seasonal cycles of euphausiid abundance were generally quite consistent over the decades,

with broad peaks from March to October, centred at about June-July (Fig. 18). Sampling in 2007 showed unusually low values everywhere in January to March, relatively normal values in the 40-45°W region in April and June and relatively low values in April east of 35°W.

West of 45°W, on the continental shelf, the abundance of hyperiid amphipods has varied during the year and the decadal patterns of these monthly variations have varied over the decades (Fig. 17). No obvious patterns emerge, however, and sampling in 2007 showed abundance levels that were equally variable with reference to previous sampling periods. East of 45°W, in the deep ocean, seasonal cycles of abundance of hyperiids were more regular and more consistent among the decades (Fig. 18). Abundance peaked between May and August in the 40-45°W region, sometime between June and September in the 35-40°W and 30-35°W regions and sometime between July and September in the 25-30°W region. In all regions, peak abundances were generally earlier in the 1990s and 2000s than in the 1960s-1980s. Abundances in 2007 were consistent with those of previous decades east of 40°W, with very low values between January and April/June, and somewhat lower values than in previous decades in June in the 40-45°W region.

5. *Limacina*

Limacina is most abundant in the fall and/or early winter on the Scotian Shelf, and similar patterns were observed farther east in the two Newfoundland Shelf regions in the 1960s and 1970s, although the cycles were less pronounced during the 1990s and 2000s (Fig. 19). Monthly abundance values for *Limacina* in 2007 were generally low between January and June on the Scotian Shelf, but relatively high values were observed on the South Newfoundland Shelf in May and June, and on the Newfoundland Shelf in March and June. East of 45°W the abundance of *Limacina* shows peaks in spring, summer or fall depending on the area and decade. Abundances of *Limacina* east of 45°W were, as expected, very low in all of the months sampled in 2007.

CONCLUDING REMARKS

A detailed analysis of the possible causes for the changes in the plankton reported here is beyond the scope of this report. It is clear, however, that decadal patterns of change in annual abundance and seasonal cycles in the plankton are very different on the Canadian continental shelf compared with deep NW Atlantic east of 45°W. It seems likely that the differences reflect regional differences in changes in environmental conditions over the years. Thus, for example, shelf regions were subjected to an increased contribution of fresh arctic water during the 1990s that had a dramatic impact on the plankton community. This appears to have been relaxing to some extent during the 2000s, but there may be lags in the system, so that, for example, that while *Calanus finmarchicus* abundance appears to be returning to pre-1990s levels (on the Scotian Shelf, at least), the abundance of the arctic *Calanus* species continues to rise or remains high. The factors that may be influencing the plankton community beyond the shelf yet to be examined, although the rising temperatures in the mid-2000s do appear to have had effects on the abundance of small zooplankton forms. Here the changes are reported; further research is required to elucidate the mechanisms causing them.

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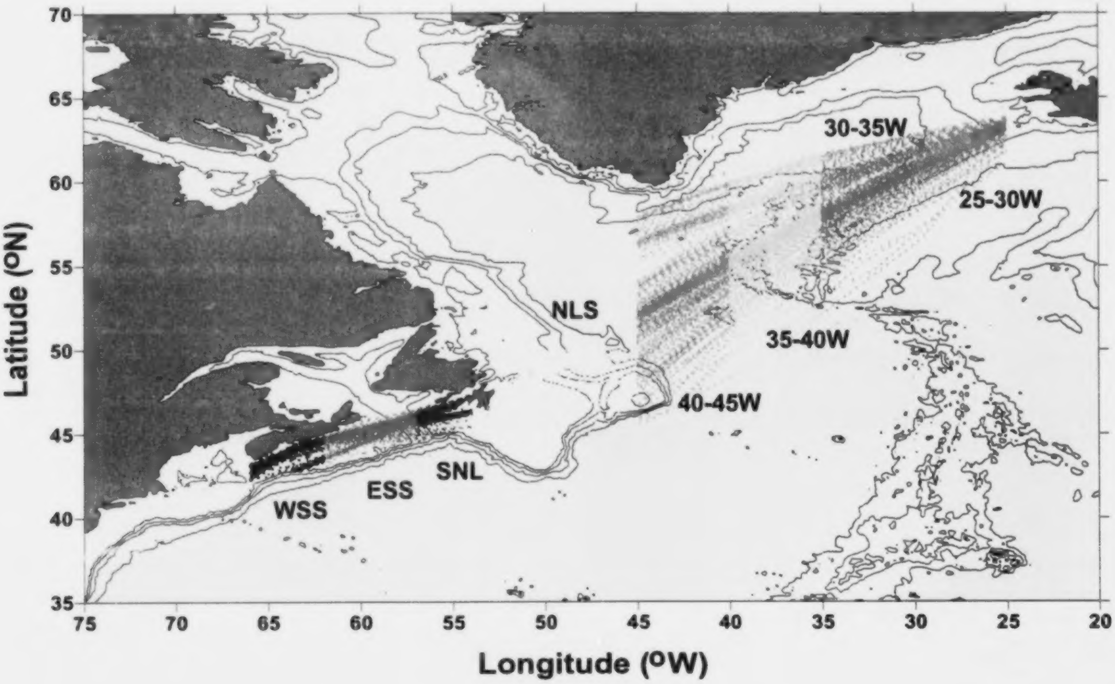

Fig.1. Positions where Continuous Plankton Recorder samples were taken between 1957 and 2007 that are included in the analyses shown in this report. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

	WSS	ESS	SNL	NLS	40-45	35-40	30-35	25-30
Mean	10.27	7.99	7.18	6.48	8.31	8.42	8.13	8.64
Std. Dev.	0.62	0.51	0.63	0.69	0.56	0.59	0.60	0.51
1960								
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1982	-0.83	-1.04	-0.72	-0.64	-1.13	-0.81	-0.58	-0.34
1983	1.21	0.86	1.38	0.58	-0.11	-0.29	-1.03	-1.38
1984	0.33	0.57	0.45	-0.45	-1.14	-1.00	-1.02	-1.08
1985	-0.52	[illegible]	[illegible]	[illegible]	[illegible]	-1.15	-0.82	-0.43
1986	-1.20	[illegible]	[illegible]	-0.99	-1.16	-1.04	-0.96	-0.99
1987	-1.40	-0.54	-0.14	-0.39	-0.13	0.02	0.00	-0.26
1988	-1.40	-0.78	0.23	0.08	0.29	0.14	0.05	-0.16
1989	-0.41	0.02	0.05	0.10	-0.73	-0.72	-0.77	-0.84
1990	-0.02	-0.43	-0.52	-0.60	-1.13	-1.21	-1.21	-0.94
1991	0.02	-0.67	-1.20	-1.37	-1.24	-1.17	-0.79	-0.47
1992	-0.74	-0.42	-0.52	-1.38	-0.82	-1.16	-1.31	-1.50
1993	0.56	0.10	-0.66	-0.75	-0.48	-0.61	-0.95	-1.20
1994	1.31	0.07	-0.23	-0.59	-0.79	-1.14	-1.10	-0.72
1995	0.78	0.23	-0.48	-0.50	-0.03	-0.31	-0.30	-0.67
1996	-1.01	-0.23	0.42	0.34	0.86	0.54	0.38	0.25
1997	-1.22	-1.32	-0.80	-0.26	0.83	1.21	1.41	1.00
1998	-0.48	0.42	0.68	1.04	1.40	1.55	1.53	1.36
1999	1.99	1.91	1.66	1.27	0.41	0.33	0.40	0.47
2000	1.80	1.82	1.81	1.55	0.87	0.22	0.14	0.32
2001	-0.13	0.75	0.08	0.62	0.90	0.88	1.30	1.21
2002	0.70	-0.31	-0.65	-0.13	0.09	0.43	0.56	0.91
2003	0.12	0.24	0.01	0.35	0.77	0.69	0.97	1.48
2004	-0.92	-0.62	0.13	0.70	0.76	0.94	0.95	1.24
2005	0.29	0.83	0.90	1.21	1.56	1.75	1.54	1.23
2006	1.17	1.90	1.80	2.20	1.85	1.92	1.59	1.52

Fig. 2. Sea–surface temperature (SST) anomalies from 1982-2006. The 1982-2006 annual average SSTs were used to generate the long-term means, which were standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

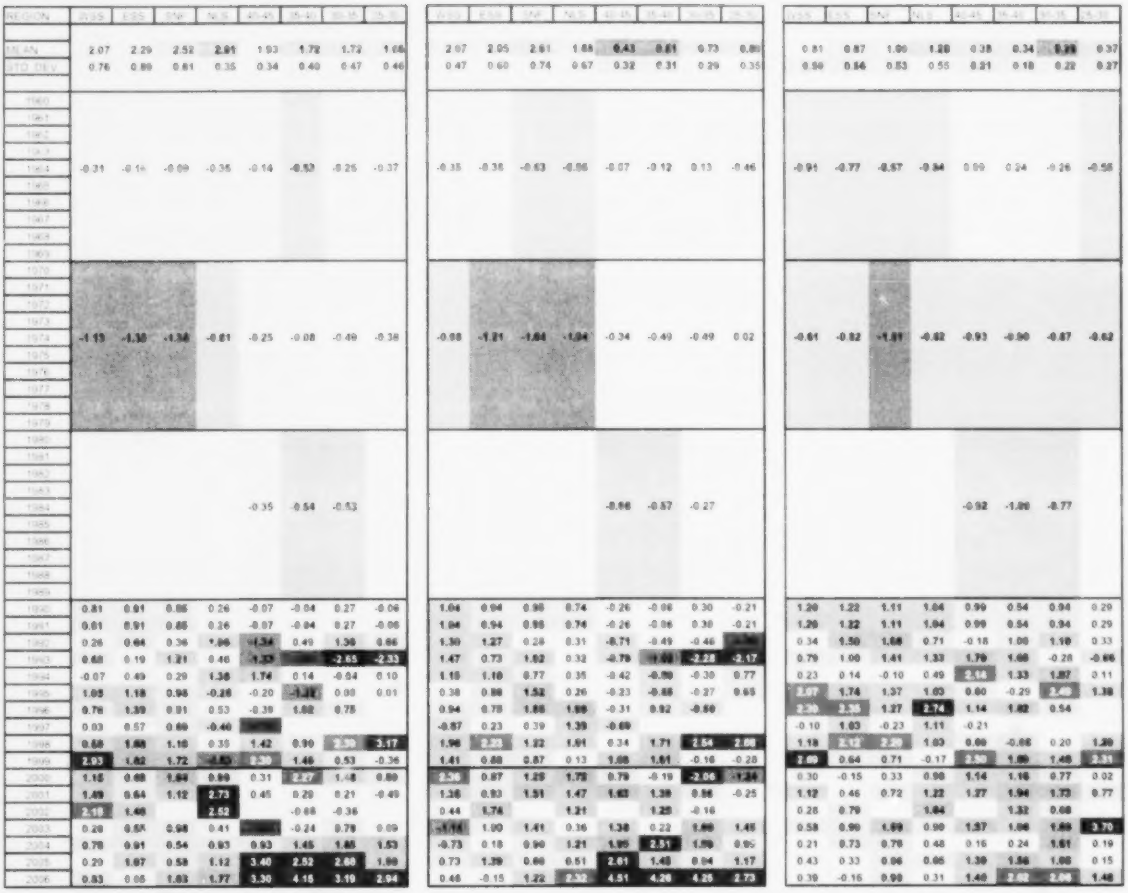
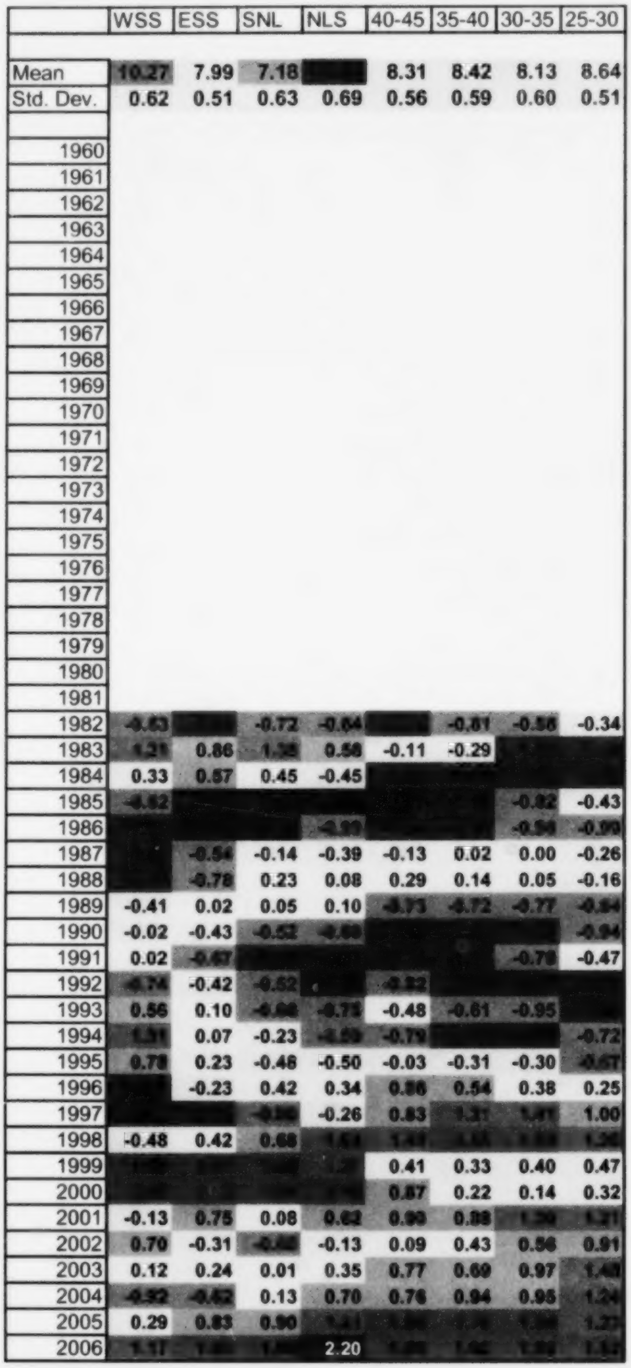


Fig. 3. Standardised abundance anomalies for diatoms (left hand column), dinoflagellates (middle column) and phytoplankton colour index (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



	WSS	ESS	SNL	NLS	40-45	35-40	30-35	25-30
Mean	10.27	7.99	7.18	[illegible]	8.31	8.42	8.13	8.64
Std. Dev.	0.62	0.51	0.63	0.69	0.56	0.59	0.60	0.51
1960								
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1982	-0.63	[illegible]	-0.72	-0.64	[illegible]	-0.81	-0.56	-0.34
1983	1.21	0.86	1.38	0.58	-0.11	-0.29	[illegible]	[illegible]
1984	0.33	0.57	0.45	-0.45	[illegible]	[illegible]	[illegible]	[illegible]
1985	-0.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.82	-0.43
1986	[illegible]	[illegible]	[illegible]	-0.93	[illegible]	[illegible]	-0.58	-0.99
1987	[illegible]	-0.54	-0.14	-0.39	-0.13	0.02	0.00	-0.26
1988	[illegible]	-0.78	0.23	0.08	0.29	0.14	0.05	-0.16
1989	-0.41	0.02	0.05	0.10	-0.73	-0.72	-0.77	-0.84
1990	-0.02	-0.43	-0.52	-0.60	[illegible]	[illegible]	[illegible]	-0.94
1991	0.02	-0.67	[illegible]	[illegible]	[illegible]	[illegible]	-0.78	-0.47
1992	-0.74	-0.42	-0.52	[illegible]	-0.82	[illegible]	[illegible]	[illegible]
1993	0.56	0.10	-0.66	-0.73	-0.48	-0.61	-0.95	[illegible]
1994	1.31	0.07	-0.23	-0.53	-0.79	[illegible]	[illegible]	-0.72
1995	0.78	0.23	-0.46	-0.50	-0.03	-0.31	-0.30	-0.67
1996	[illegible]	-0.23	0.42	0.34	0.86	0.54	0.38	0.25
1997	[illegible]	[illegible]	-0.86	-0.26	0.83	1.31	1.41	1.00
1998	-0.48	0.42	0.68	1.51	1.41	[illegible]	[illegible]	1.36
1999	[illegible]	[illegible]	[illegible]	[illegible]	0.41	0.33	0.40	0.47
2000	[illegible]	[illegible]	[illegible]	[illegible]	0.87	0.22	0.14	0.32
2001	-0.13	0.75	0.08	0.62	0.90	0.88	1.30	1.21
2002	0.70	-0.31	-0.60	-0.13	0.09	0.43	0.56	0.91
2003	0.12	0.24	0.01	0.35	0.77	0.69	0.97	1.40
2004	-0.92	-0.62	0.13	0.70	0.76	0.94	0.95	1.24
2005	0.29	0.83	0.90	1.41	[illegible]	[illegible]	[illegible]	1.27
2006	1.11	[illegible]	[illegible]	2.20	[illegible]	1.92	[illegible]	1.14

Fig. 2. Sea–surface temperature (SST) anomalies from 1982-2006. The 1982-2006 annual average SSTs were used to generate the long-term means, which were standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

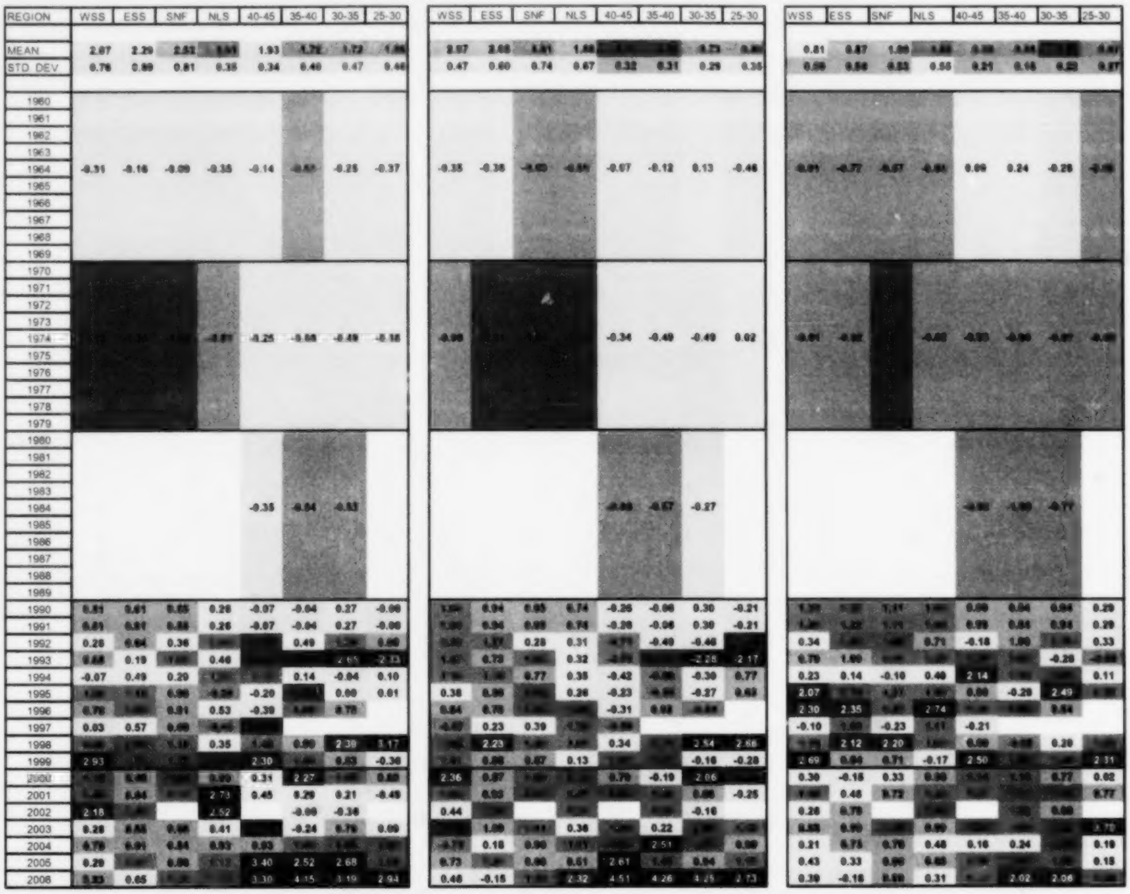
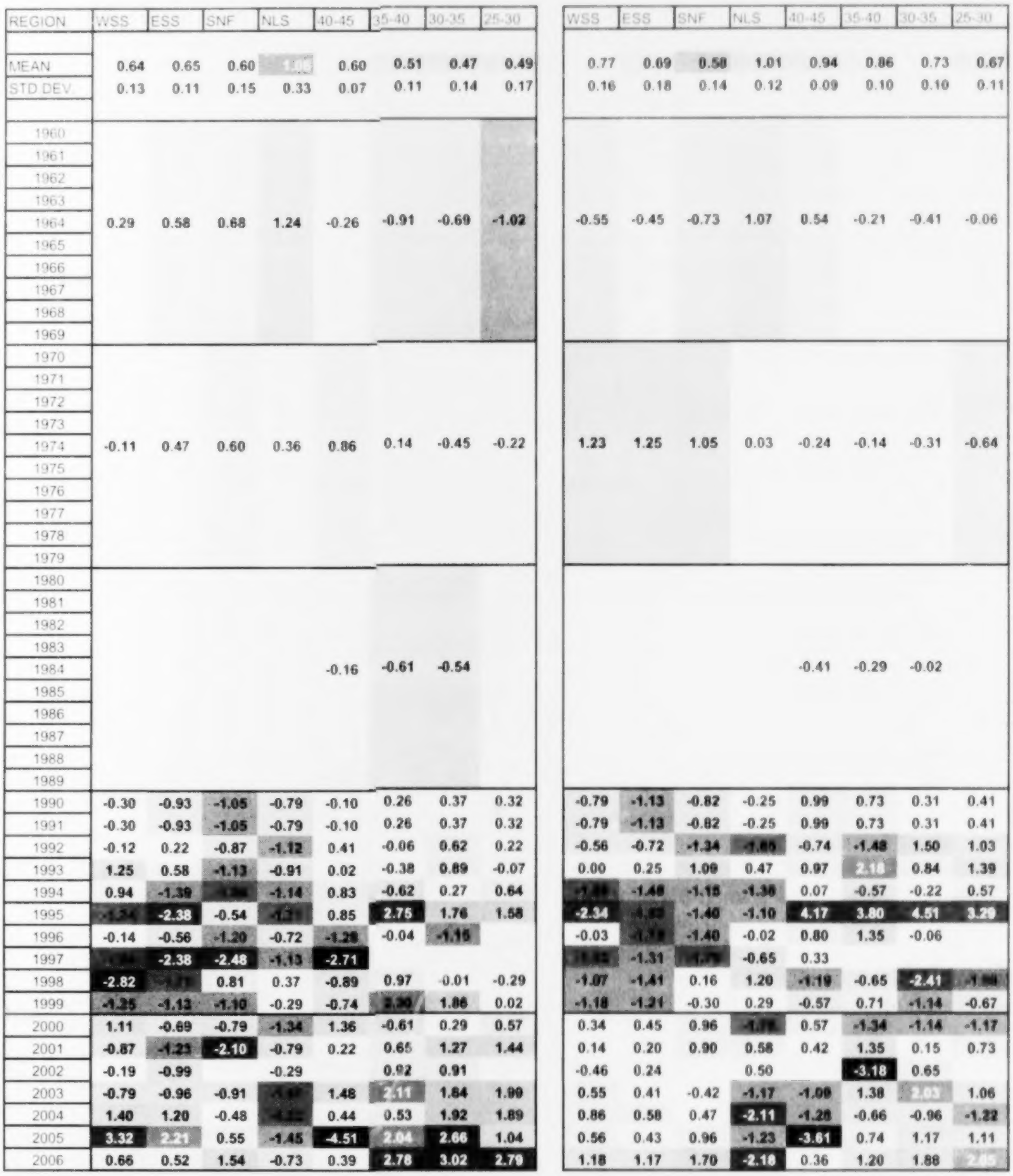


Fig. 3. Standardised abundance anomalies for diatoms (left hand column), dinoflagellates (middle column) and phytoplankton colour index (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.64	0.65	0.60	[illegible]	0.60	0.51	0.47	0.49	0.77	0.69	0.50	1.01	0.94	0.86	0.73	0.67
STD DEV.	0.13	0.11	0.15	0.33	0.07	0.11	0.14	0.17	0.16	0.18	0.14	0.12	0.09	0.10	0.10	0.11
1960																
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1964	0.29	0.58	0.68	1.24	-0.26	-0.91	-0.69	-1.02	-0.55	-0.45	-0.73	1.07	0.54	-0.21	-0.41	-0.06
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1974	-0.11	0.47	0.60	0.36	0.86	0.14	-0.45	-0.22	1.23	1.25	1.05	0.03	-0.24	-0.14	-0.31	-0.64
1975																
1976																
1977																
1978																
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1980																
1981																
1982																
1983																
1984					-0.16	-0.61	-0.54						-0.41	-0.29	-0.02	
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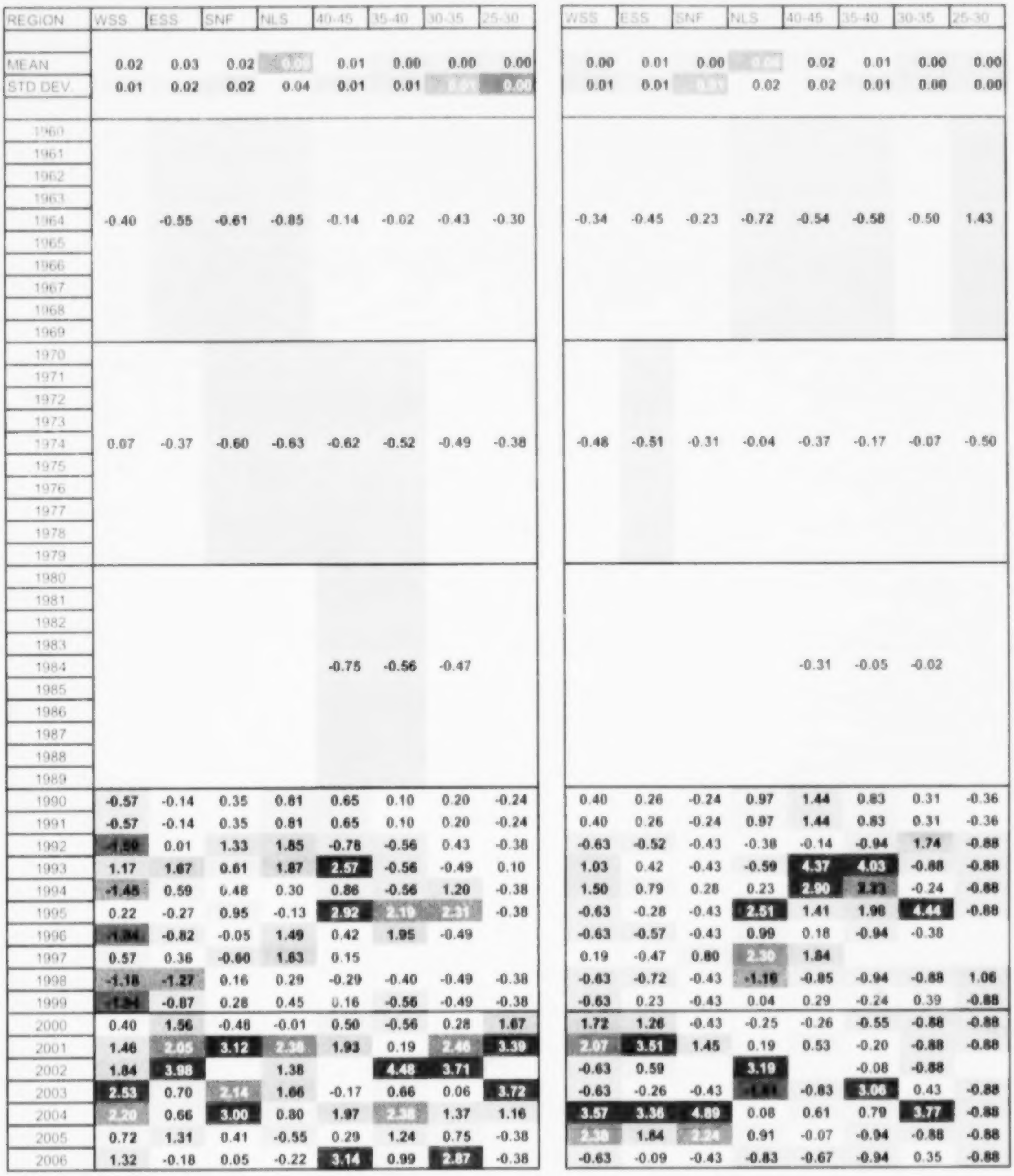
1987																
1988																
1989																
1990	-0.30	-0.93	-1.05	-0.79	-0.10	0.26	0.37	0.32	-0.79	-1.13	-0.82	-0.25	0.99	0.73	0.31	0.41
1991	-0.30	-0.93	-1.05	-0.79	-0.10	0.26	0.37	0.32	-0.79	-1.13	-0.82	-0.25	0.99	0.73	0.31	0.41
1992	-0.12	0.22	-0.87	-1.12	0.41	-0.06	0.62	0.22	-0.56	-0.72	-1.34	[illegible]	-0.74	-1.48	1.50	1.03
1993	1.25	0.58	-1.13	-0.91	0.02	-0.38	0.89	-0.07	0.00	0.25	1.09	0.47	0.97	2.18	0.84	1.39
1994	0.94	-1.39	[illegible]	-1.14	0.83	-0.62	0.27	0.64	[illegible]	-1.48	-1.15	-1.38	0.07	-0.57	-0.22	0.57
1995	[illegible]	-2.38	-0.54	[illegible]	0.85	2.75	1.76	1.58	-2.34	[illegible]	-1.40	-1.10	4.17	3.80	4.51	3.29
1996	-0.14	-0.56	-1.20	-0.72	-1.28	-0.04	-1.15		-0.03	[illegible]	-1.40	-0.02	0.80	1.35	-0.06	
1997	[illegible]	-2.38	-2.48	-1.13	-2.71				[illegible]	-1.31	[illegible]	-0.65	0.33			
1998	-2.82	[illegible]	0.81	0.37	-0.89	0.97	-0.01	-0.29	-1.07	-1.41	0.16	1.20	-1.19	-0.65	-2.41	[illegible]
1999	-1.25	-1.13	-1.10	-0.29	-0.74	[illegible]	1.86	0.02	-1.18	-1.21	-0.30	0.29	-0.57	0.71	-1.14	-0.67
2000	1.11	-0.69	-0.79	-1.34	1.36	-0.61	0.29	0.57	0.34	0.45	0.96	[illegible]	0.57	-1.34	-1.14	-1.17
2001	-0.87	-1.23	-2.10	-0.79	0.22	0.65	1.27	1.44	0.14	0.20	0.90	0.58	0.42	1.35	0.15	0.73
2002	-0.19	-0.99		-0.29		0.92	0.91		-0.46	0.24		0.50		-3.18	0.65	
2003	-0.79	-0.96	-0.91	[illegible]	1.48	2.11	1.84	1.99	0.55	0.41	-0.42	-1.17	-1.09	1.38	2.03	1.06
2004	1.40	1.20	-0.48	[illegible]	0.44	0.53	1.92	1.89	0.86	0.58	0.47	-2.11	-1.28	-0.66	-0.96	-1.22
2005	3.32	2.21	0.55	-1.45	-4.51	2.04	2.66	1.04	0.56	0.43	0.96	-1.23	-3.61	0.74	1.17	1.11
2006	0.66	0.52	1.54	-0.73	0.39	2.78	3.02	2.79	1.18	1.17	1.70	-2.18	0.36	1.20	1.88	2.05

Fig. 4. Standardised abundance anomalies for *Calanus* I-IV (left hand column) and *Calanus finmarchicus* V-VI (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.02	0.03	0.02	0.00	0.01	0.00	0.00	0.00
STD DEV.	0.01	0.02	0.02	0.04	0.01	0.01	0.01	0.00
1960								
1961								
1962								
1963								
1964	-0.40	-0.55	-0.61	-0.85	-0.14	-0.02	-0.43	-0.30
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972								
1973								
1974	0.07	-0.37	-0.60	-0.63	-0.62	-0.52	-0.49	-0.38
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984					-0.75	-0.56	-0.47	
1985								
1986								
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1989								
1990	-0.57	-0.14	0.35	0.81	0.65	0.10	0.20	-0.24
1991	-0.57	-0.14	0.35	0.81	0.65	0.10	0.20	-0.24
1992	-1.59	0.01	1.33	1.85	-0.78	-0.56	0.43	-0.38
1993	1.17	1.67	0.61	1.87	2.57	-0.56	-0.49	0.10
1994	-1.45	0.59	0.48	0.30	0.86	-0.56	1.20	-0.38
1995	0.22	-0.27	0.95	-0.13	2.92	2.19	2.31	-0.38
1996	-1.84	-0.82	-0.05	1.49	0.42	1.95	-0.49	
1997	0.57	0.36	-0.60	1.63	0.15			
1998	-1.18	-1.27	0.16	0.29	-0.29	-0.40	-0.49	-0.38
1999	-1.84	-0.87	0.28	0.45	0.16	-0.56	-0.49	-0.38
2000	0.40	1.56	-0.48	-0.01	0.50	-0.56	0.28	1.67
2001	1.46	2.05	3.12	2.38	1.93	0.19	2.46	3.39
2002	1.84	3.98		1.38		4.48	3.71	
2003	2.53	0.70	2.14	1.66	-0.17	0.66	0.06	3.72
2004	2.20	0.66	3.00	0.80	1.97	2.38	1.37	1.16
2005	0.72	1.31	0.41	-0.55	0.29	1.24	0.75	-0.38
2006	1.32	-0.18	0.05	-0.22	3.14	0.99	2.87	-0.38

REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.00	0.01	0.00	0.02	0.02	0.01	0.00	0.00
STD DEV.	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00
1960								
1961								
1962								
1963								
1964	-0.34	-0.45	-0.23	-0.72	-0.54	-0.58	-0.50	1.43
1965								
1966								
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1971								
1972								
1973								
1974	-0.48	-0.51	-0.31	-0.04	-0.37	-0.17	-0.07	-0.50
1975								
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1983								
1984					-0.31	-0.05	-0.02	
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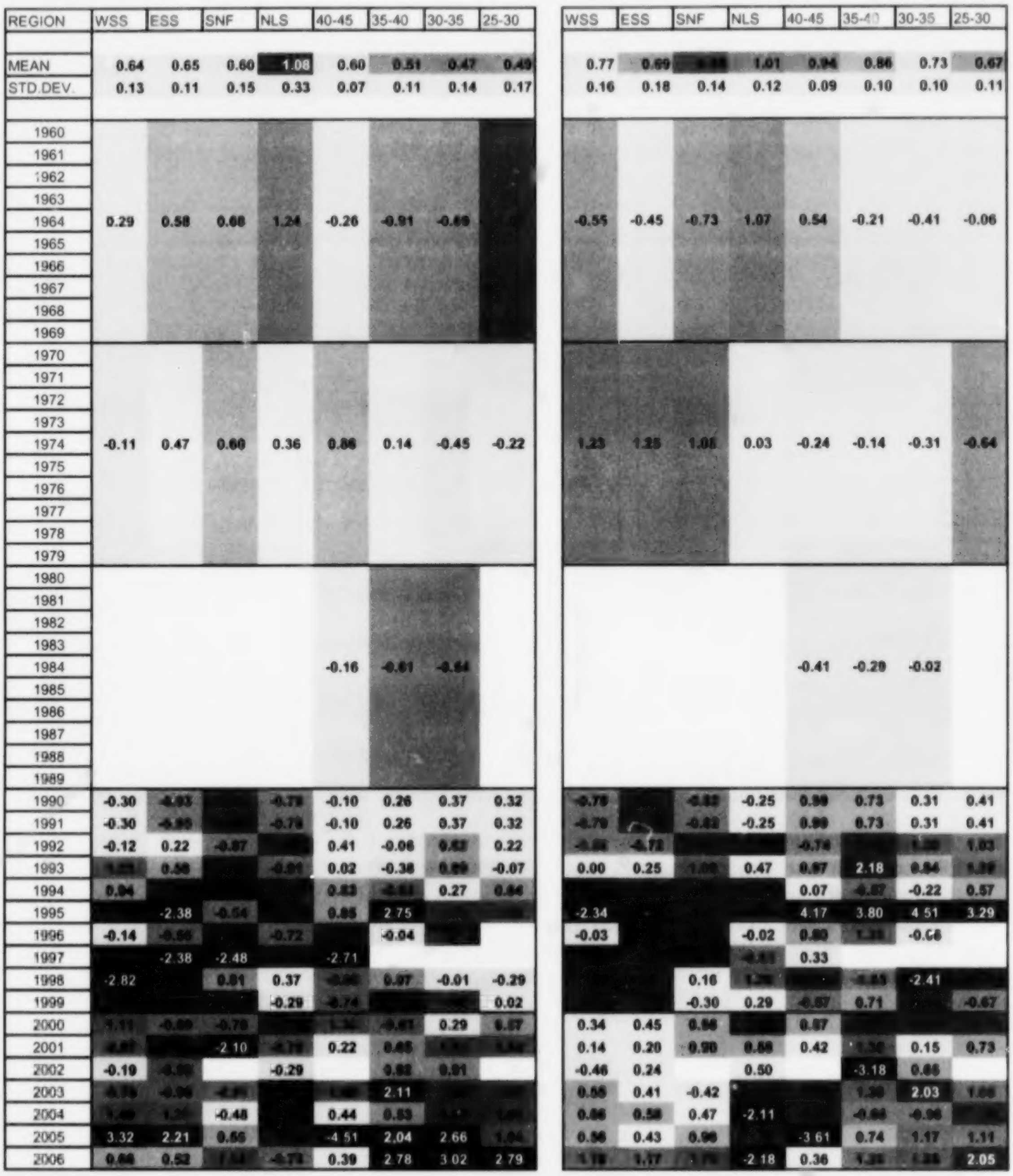
1987								
1988								
1989								
1990	0.40	0.26	-0.24	0.97	1.44	0.83	0.31	-0.36
1991	0.40	0.26	-0.24	0.97	1.44	0.83	0.31	-0.36
1992	-0.63	-0.52	-0.43	-0.38	-0.14	-0.94	1.74	-0.88
1993	1.03	0.42	-0.43	-0.59	4.37	4.03	-0.88	-0.88
1994	1.50	0.79	0.28	0.23	2.90	2.23	-0.24	-0.88
1995	-0.63	-0.28	-0.43	2.51	1.41	1.98	4.44	-0.88
1996	-0.63	-0.57	-0.43	0.99	0.18	-0.94	-0.38	
1997	0.19	-0.47	0.80	2.30	1.84			
1998	-0.63	-0.72	-0.43	-1.16	-0.85	-0.94	-0.88	1.06
1999	-0.63	0.23	-0.43	0.04	0.29	-0.24	0.39	-0.88
2000	1.72	1.26	-0.43	-0.25	-0.26	-0.55	-0.88	-0.88
2001	2.07	3.51	1.45	0.19	0.53	-0.20	-0.88	-0.88
2002	-0.63	0.59		3.19		-0.08	-0.88	
2003	-0.63	-0.26	-0.43	-1.81	-0.83	3.06	0.43	-0.88
2004	3.57	3.36	4.89	0.08	0.61	0.79	3.77	-0.88
2005	2.38	1.84	2.24	0.91	-0.07	-0.94	-0.88	-0.88
2006	-0.63	-0.09	-0.43	-0.83	-0.67	-0.94	0.35	-0.88

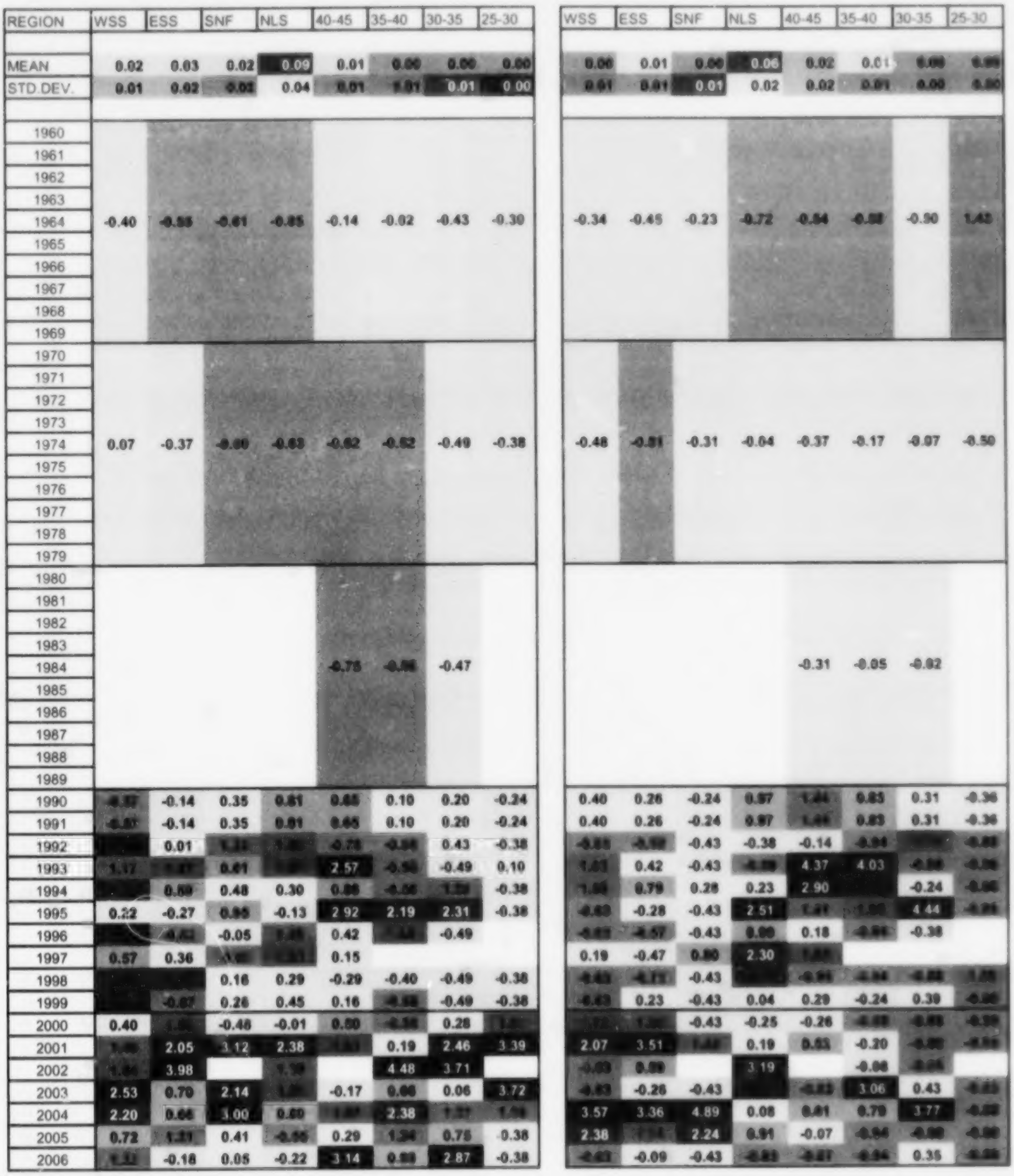
Fig. 5. Standardised abundance anomalies for *Calanus glacialis* (left hand column) and *Calanus hyperboreus* (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.64	0.65	0.60	1.08	0.60	0.51	0.47	0.49
STD.DEV.	0.13	0.11	0.15	0.33	0.07	0.11	0.14	0.17
1960	0.29	0.58	0.68	1.24	-0.26	-0.91	-0.69	[illegible]
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	-0.11	0.47	0.60	0.36	0.86	0.14	-0.45	-0.22
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.16	-0.81	-0.64	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	-0.30	-0.93	[illegible]	-0.79	-0.10	0.26	0.37	0.32
1991	-0.30	-0.89	[illegible]	-0.78	-0.10	0.26	0.37	0.32
1992	-0.12	0.22	-0.87	[illegible]	0.41	-0.06	0.62	0.22
1993	[illegible]	0.56	[illegible]	-0.91	0.02	-0.38	0.89	-0.07
1994	0.94	[illegible]	[illegible]	[illegible]	0.83	[illegible]	0.27	0.64
1995	[illegible]	-2.38	-0.54	[illegible]	0.86	2.75	[illegible]	[illegible]
1996	-0.14	-0.66	[illegible]	-0.72	[illegible]	-0.04	[illegible]	
1997	[illegible]	-2.38	-2.48	[illegible]	-2.71			
1998	-2.82	[illegible]	0.81	0.37	[illegible]	0.07	-0.01	-0.29
1999	[illegible]	[illegible]	[illegible]	-0.29	-0.74	[illegible]	[illegible]	0.02
2000	[illegible]	-0.69	-0.78	[illegible]	[illegible]	-0.61	0.29	0.67
2001	[illegible]	[illegible]	-2.10	[illegible]	0.22	0.65	[illegible]	[illegible]
2002	-0.19	[illegible]		-0.29		0.92	0.91	
2003	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.11	[illegible]	[illegible]
2004	[illegible]	[illegible]	-0.48	[illegible]	0.44	0.83	[illegible]	[illegible]
2005	3.32	2.21	0.66	[illegible]	-4.51	2.04	2.66	[illegible]
2006	0.66	0.52	[illegible]	-0.73	0.39	2.78	3.02	2.79

REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.77	0.69	[illegible]	1.01	0.94	0.86	0.73	0.67
STD.DEV.	0.16	0.18	0.14	0.12	0.09	0.10	0.10	0.11
1960	-0.55	-0.45	-0.73	1.07	0.54	-0.21	-0.41	-0.06
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	1.23	1.25	1.08	0.03	-0.24	-0.14	-0.31	-0.64
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.41	-0.29	-0.02	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	-0.79	[illegible]	-0.83	-0.25	0.99	0.73	0.31	0.41
1991	-0.79	[illegible]	-0.83	-0.25	0.99	0.73	0.31	0.41
1992	[illegible]	-0.73	[illegible]	[illegible]	-0.74	[illegible]	[illegible]	1.03
1993	0.00	0.25	[illegible]	0.47	0.97	2.18	0.84	[illegible]
1994	[illegible]	[illegible]	[illegible]	[illegible]	0.07	-0.87	-0.22	0.57
1995	-2.34	[illegible]	[illegible]	[illegible]	4.17	3.80	4.51	3.29
1996	-0.03	[illegible]	[illegible]	-0.02	0.80	[illegible]	-0.68	
1997	[illegible]	[illegible]	[illegible]	[illegible]	0.33			
1998	[illegible]	[illegible]	0.16	[illegible]	[illegible]	[illegible]	-2.41	[illegible]
1999	[illegible]	[illegible]	-0.30	0.29	-0.57	0.71	[illegible]	-0.67
2000	0.34	0.45	0.96	[illegible]	0.87	[illegible]	[illegible]	[illegible]
2001	0.14	0.20	0.90	0.86	0.42	[illegible]	0.15	0.73
2002	-0.46	0.24		0.50		-3.18	0.86	
2003	0.65	0.41	-0.42	[illegible]	[illegible]	[illegible]	2.03	[illegible]
2004	0.86	0.58	0.47	-2.11	[illegible]	-0.86	-0.96	[illegible]
2005	0.56	0.43	0.96	[illegible]	-3.61	0.74	1.17	1.11
2006	[illegible]	1.17	[illegible]	-2.18	0.36	[illegible]	[illegible]	2.05

Fig. 4. Standardised abundance anomalies for *Calanus* I-IV (left hand column) and *Calanus finmarchicus* V-VI (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.02	0.03	0.02	0.09	0.01	0.00	0.00	0.00
STD.DEV.	0.01	0.02	0.02	0.04	0.01	0.01	0.01	0.00
1960	-0.40	-0.56	-0.61	-0.85	-0.14	-0.02	-0.43	-0.30
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	0.07	-0.37	-0.60	-0.63	-0.62	-0.52	-0.49	-0.38
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.75	-0.86	-0.47	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	-0.37	-0.14	0.35	0.61	0.65	0.10	0.20	-0.24
1991	[illegible]	-0.14	0.35	0.61	0.65	0.10	0.20	-0.24
1992	[illegible]	0.01	1.11	[illegible]	-0.78	-0.84	0.43	-0.38
1993	1.17	[illegible]	0.61	[illegible]	2.57	-0.56	-0.49	0.10
1994	[illegible]	0.69	0.48	0.30	0.86	-0.06	1.29	-0.38
1995	0.22	-0.27	0.95	-0.13	2.92	2.19	2.31	-0.38
1996	[illegible]	-0.62	-0.05	[illegible]	0.42	[illegible]	-0.49	
1997	0.57	0.36	[illegible]	[illegible]	0.15			
1998	[illegible]	[illegible]	0.16	0.29	-0.29	-0.40	-0.49	-0.38
1999	[illegible]	-0.67	0.26	0.45	0.16	[illegible]	-0.49	-0.38
2000	0.40	[illegible]	-0.46	-0.01	0.50	[illegible]	0.28	[illegible]
2001	[illegible]	2.05	3.12	2.38	[illegible]	0.19	2.46	3.39
2002	[illegible]	3.98		[illegible]		4.48	3.71	
2003	2.53	0.70	2.14	[illegible]	-0.17	0.66	0.06	3.72
2004	2.20	0.66	3.00	0.60	[illegible]	2.38	[illegible]	[illegible]
2005	0.72	1.21	0.41	-0.06	0.29	1.34	0.75	-0.38
2006	[illegible]	-0.18	0.05	-0.22	3.14	0.89	2.87	-0.38

REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.00	0.01	0.00	0.06	0.02	0.01	0.00	0.00
STD.DEV.	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00
1960	-0.34	-0.45	-0.23	-0.72	-0.84	-0.88	-0.90	1.43
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	-0.48	-0.51	-0.31	-0.04	-0.37	-0.17	-0.07	-0.50
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.31	-0.05	-0.02	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	0.40	0.26	-0.24	0.97	1.44	0.83	0.31	-0.36
1991	0.40	0.26	-0.24	0.97	1.44	0.83	0.31	-0.36
1992	-0.85	-0.59	-0.43	-0.38	-0.14	-0.84	[illegible]	-0.83
1993	1.01	0.42	-0.43	-0.39	4.37	4.03	-0.58	-0.39
1994	1.86	0.79	0.28	0.23	2.90	[illegible]	-0.24	-0.86
1995	-0.63	-0.28	-0.43	2.51	1.41	1.96	4.44	-0.81
1996	-0.83	-0.57	-0.43	0.99	0.18	-0.86	-0.38	
1997	0.19	-0.47	0.80	2.30	1.88			
1998	-0.63	-0.75	-0.43	[illegible]	-0.91	-0.84	-0.82	1.05
1999	-0.63	0.23	-0.43	0.04	0.29	-0.24	0.39	-0.86
2000	[illegible]	[illegible]	-0.43	-0.25	-0.26	-0.83	-0.83	-0.39
2001	2.07	3.51	1.48	0.19	0.53	-0.20	-0.85	-0.85
2002	-0.63	0.99		3.19		-0.06	-0.05	
2003	-0.63	-0.26	-0.43	[illegible]	-0.83	3.06	0.43	-0.83
2004	3.57	3.36	4.89	0.08	0.61	0.79	3.77	-0.83
2005	2.38	[illegible]	2.24	0.91	-0.07	-0.84	-0.88	-0.88
2006	-0.63	-0.09	-0.43	-0.83	-0.81	-0.84	0.35	-0.86

Fig. 5. Standardised abundance anomalies for *Calanus glacialis* (left hand column) and *Calanus hyperboreus* (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	1.40	1.22	1.31	0.65	0.12	0.08	0.10	0.12
STD DEV	0.28	0.17	0.20	0.12	0.08	0.09	0.10	0.13
1960								
1961								
1962								
1963								
1964	0.39	-0.26	0.32	0.00	-0.71	-0.60	-0.45	-0.69
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972								
1973								
1974	0.18	-0.11	-0.15	-1.15	-0.06	-0.31	-0.54	-0.41
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984					-0.82	-0.68	-0.55	
1985								
1986								
1987								
1988								
1989								
1990	0.13	0.77	0.15	0.97	0.54	0.31	0.34	0.10
1991	0.13	0.77	0.15	0.97	0.54	0.31	0.34	0.10
1992	0.51	1.73	-0.80	1.01	-0.63	0.00	-0.01	-0.58
1993	3.01	3.31	2.87	2.91	0.34	-0.70	0.00	-0.65
1994	0.46	0.09	0.70	-0.24	1.16	-0.04	0.75	-0.35
1995	-0.39	0.83	-1.09	0.00	1.20	1.47	0.79	1.01
1996	-2.09	0.78	-0.13	1.56	0.21	0.41	-0.47	
1997	-2.51	[illegible]	-1.32	0.22	-0.27			
1998	-0.47	0.87	1.44	0.66	-0.37	0.62	1.41	1.37
1999	0.91	0.98	0.79	1.85	3.07	2.43	1.08	0.88
2000	1.57	0.87	1.52	0.08	0.58	1.06	0.59	0.29
2001	-0.98	0.01	-0.93	0.89	1.58	1.23	0.75	0.38
2002	[illegible]	-2.28		0.97		-0.26	0.42	
2003	-2.03	[illegible]	-2.48	-1.52	1.74	0.89	2.56	2.44
2004	-0.96	[illegible]	-2.95	0.10	2.70	2.34	4.47	2.94
2005	-0.54	1.03	0.73	1.00	2.24	2.56	0.42	0.39
2006	-0.53	-0.65	-0.37	0.04	1.22	3.31	2.07	2.65

	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.34	0.22	0.14	0.36	0.69	0.65	0.61	0.51
STD DEV	0.22	0.10	0.07	0.18	0.30	0.23	0.22	0.20
1960								
1961								
1962								
1963								
1964								
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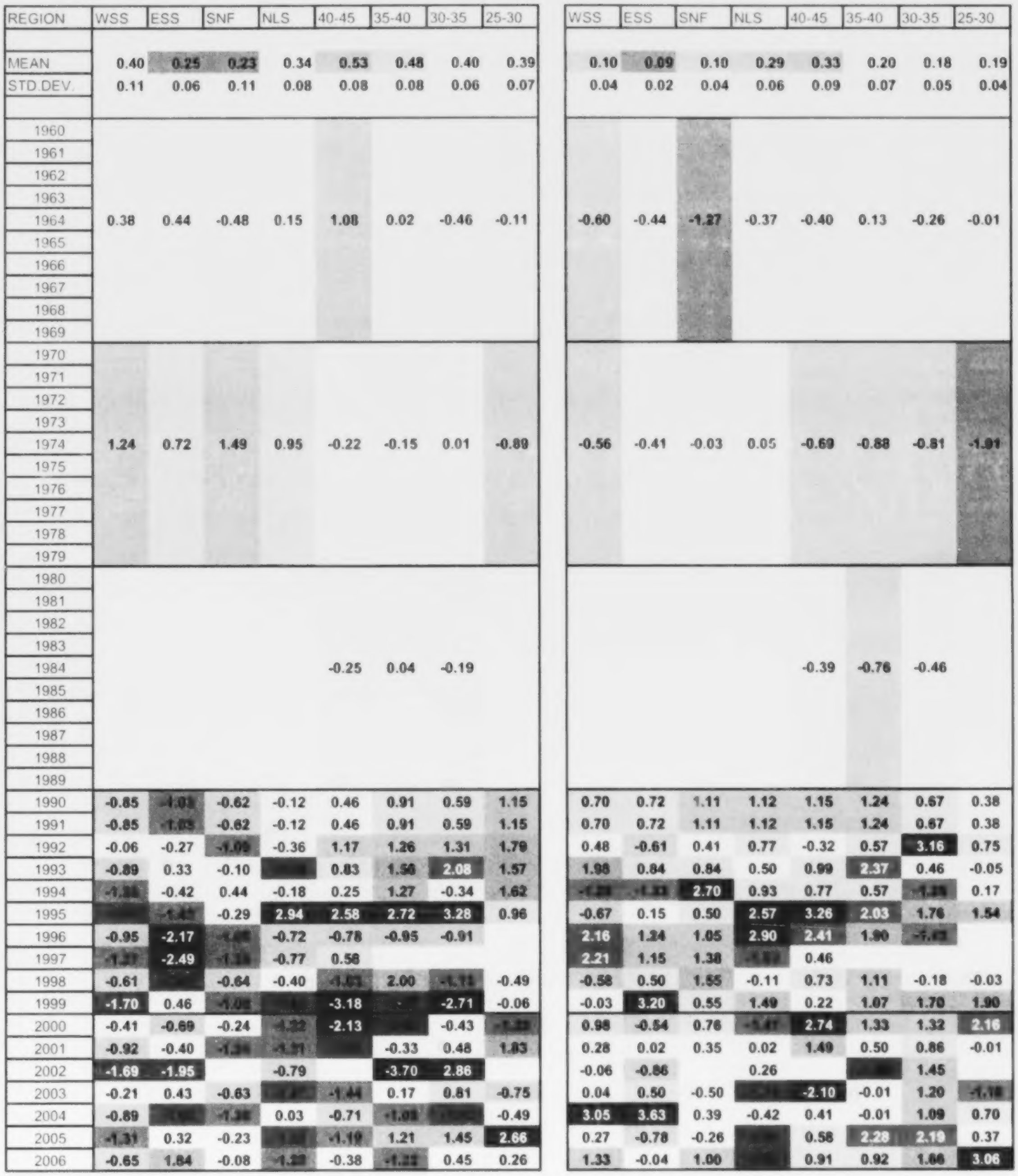
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	0.25	0.08	-0.42	-0.43	-0.27	-0.54	-0.55	-0.46
1991	0.25	0.08	-0.42	-0.43	-0.27	-0.54	-0.55	-0.46
1992	-1.35	-1.37	[illegible]	[illegible]	[illegible]	[illegible]	-2.15	[illegible]
1993	0.98	-0.79	-0.51	-1.44	-0.62	-0.67	-0.82	-0.71
1994	-0.44	-0.38	-0.15	-0.67	0.23	0.03	-0.65	-0.02
1995	0.51	0.81	0.24	0.35	0.59	-0.23	0.74	1.31
1996	1.72	0.99	-0.65	1.37	0.11	0.70	0.57	
1997	-0.80	-0.43	-1.35	-0.86	-0.82			
1998	1.15	1.40	0.97	0.15	0.50	0.63	1.21	1.47
1999	1.35	2.12	1.75	-0.60	0.59	0.92	0.10	-0.03
2000	1.24	1.05	1.31	0.14	-0.34	-1.10	-0.93	-0.88
2001	-0.87	-0.44	0.55	1.97	-0.02	0.77	0.46	-0.14
2002	[illegible]	0.14		-0.11		-0.98	-0.81	
2003	-0.95	-1.21	-0.50	0.09	-1.40	-1.00	0.20	-0.69
2004	[illegible]	[illegible]	-0.41	0.89	-0.28	0.18	0.31	-0.04
2005	-0.82	-0.43	1.27	-0.54	1.24	1.11	1.85	1.24
2006	-0.20	-0.18	0.29	1.63	2.48	2.21	1.02	1.33

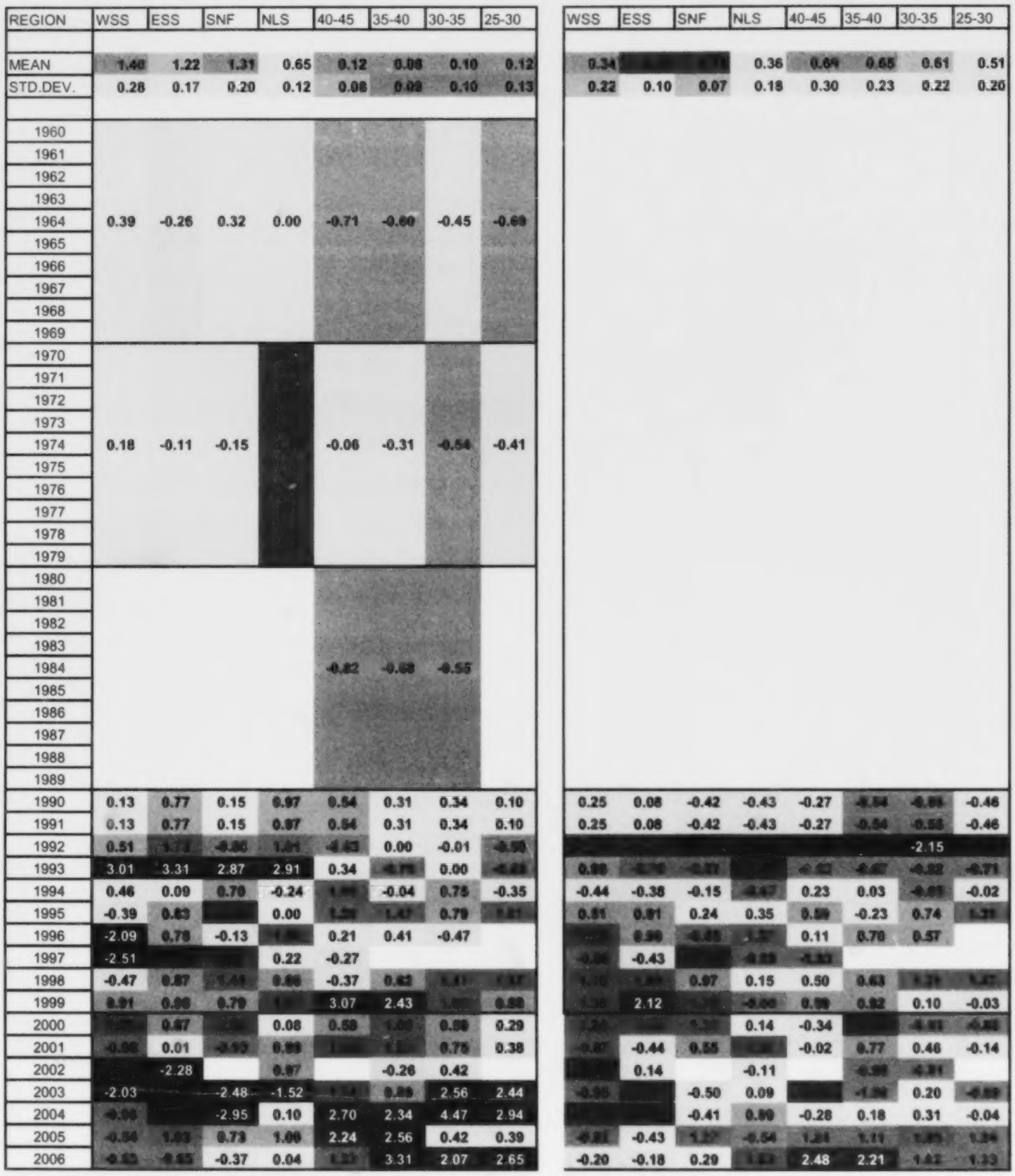
Fig. 6. Standardised abundance anomalies for small copepods (*Paracalanus/Pseudocalanus*, left hand column) and foramnifera (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.40	0.25	0.23	0.34	0.53	0.48	0.40	0.39
STD.DEV.	0.11	0.06	0.11	0.08	0.08	0.08	0.06	0.07
1960								
1961								
1962								
1963								
1964	0.38	0.44	-0.48	0.15	1.08	0.02	-0.46	-0.11
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972								
1973								
1974	1.24	0.72	1.49	0.95	-0.22	-0.15	0.01	-0.89
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984					-0.25	0.04	-0.19	
1985								
1986								
1987								
1988								
1989								
1990	-0.85	[illegible]	-0.62	-0.12	0.46	0.91	0.59	1.15
1991	-0.85	[illegible]	-0.62	-0.12	0.46	0.91	0.59	1.15
1992	-0.06	-0.27	[illegible]	-0.36	1.17	1.26	1.31	1.79
1993	-0.89	0.33	-0.10	[illegible]	0.83	1.56	2.08	1.57
1994	[illegible]	-0.42	0.44	-0.18	0.25	1.27	-0.34	1.62
1995	[illegible]	[illegible]	-0.29	2.94	2.58	2.72	3.28	0.96
1996	-0.95	-2.17	[illegible]	-0.72	-0.78	-0.95	-0.91	
1997	[illegible]	-2.49	[illegible]	-0.77	0.56			
1998	-0.61	[illegible]	-0.64	-0.40	[illegible]	2.00	[illegible]	-0.49
1999	-1.70	0.46	[illegible]	[illegible]	-3.18	[illegible]	-2.71	-0.06
2000	-0.41	-0.69	-0.24	-1.22	-2.13	[illegible]	-0.43	[illegible]
2001	-0.92	-0.40	[illegible]	[illegible]	[illegible]	-0.33	0.48	1.83
2002	-1.69	-1.95		-0.79		-3.70	2.86	
2003	-0.21	0.43	-0.63	[illegible]	-1.44	0.17	0.81	-0.75
2004	-0.89	[illegible]	-1.38	0.03	-0.71	-1.08	[illegible]	-0.49
2005	-1.31	0.32	-0.23	[illegible]	-1.19	1.21	1.45	2.66
2006	-0.65	1.84	-0.08	-1.28	-0.38	-1.22	0.45	0.26

	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.10	0.09	0.10	0.29	0.33	0.20	0.18	0.19
STD.DEV.	0.04	0.02	0.04	0.06	0.09	0.07	0.05	0.04
1960								
1961								
1962								
1963								
1964	-0.60	-0.44	-1.27	-0.37	-0.40	0.13	-0.26	-0.01
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972								
1973								
1974	-0.56	-0.41	-0.03	0.05	-0.69	-0.88	-0.81	-1.91
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984					-0.39	-0.76	-0.46	
1985								
1986								
1987								
1988								
1989								
1990	0.70	0.72	1.11	1.12	1.15	1.24	0.67	0.38
1991	0.70	0.72	1.11	1.12	1.15	1.24	0.67	0.38
1992	0.48	-0.61	0.41	0.77	-0.32	0.57	3.16	0.75
1993	1.98	0.84	0.84	0.50	0.99	2.37	0.46	-0.05
1994	[illegible]	[illegible]	2.70	0.93	0.77	0.57	[illegible]	0.17
1995	-0.67	0.15	0.50	2.57	3.26	2.03	1.76	1.54
1996	2.16	1.24	1.05	2.90	2.41	1.90	[illegible]	
1997	2.21	1.15	1.38	[illegible]	0.46			
1998	-0.58	0.50	1.55	-0.11	0.73	1.11	-0.18	-0.03
1999	-0.03	3.20	0.55	1.49	0.22	1.07	1.70	1.90
2000	0.98	-0.54	0.76	[illegible]	2.74	1.33	1.32	2.16
2001	0.28	0.02	0.35	0.02	1.49	0.50	0.86	-0.01
2002	-0.06	-0.86		0.26		[illegible]	1.45	
2003	0.04	0.50	-0.50	[illegible]	-2.10	-0.01	1.20	[illegible]
2004	3.05	3.63	0.39	-0.42	0.41	-0.01	1.09	0.70
2005	0.27	-0.78	-0.26	[illegible]	0.58	2.28	2.19	0.37
2006	1.33	-0.04	1.00	[illegible]	0.91	0.92	1.66	3.06

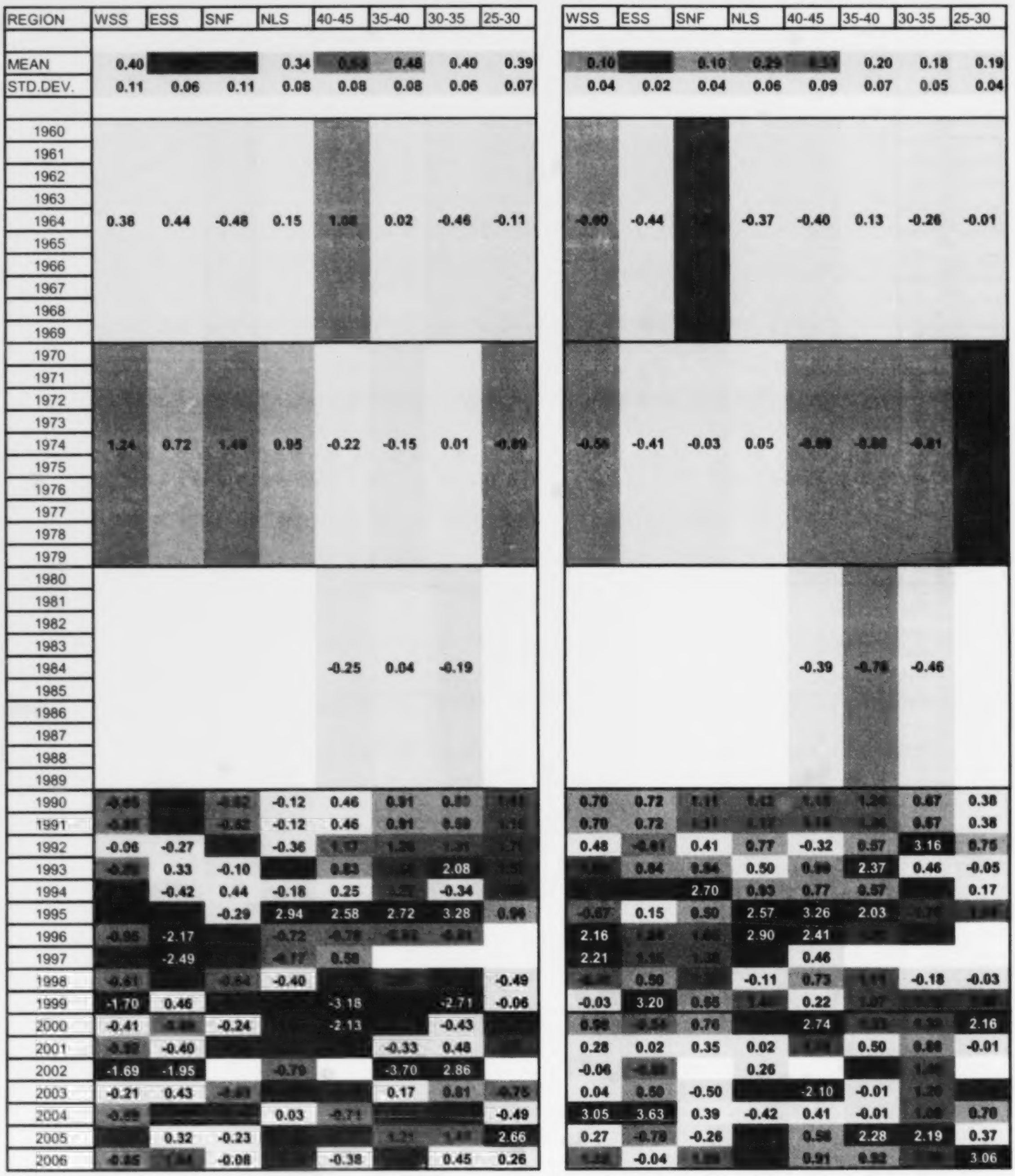
Fig. 7. Standardised abundance anomalies for euphausiids (left hand column) and hyperiids (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	1.40	1.22	1.31	0.65	0.12	0.08	0.10	0.12
STD.DEV.	0.28	0.17	0.20	0.12	0.08	0.08	0.10	0.13
1960								
1961								
1962								
1963								
1964	0.39	-0.26	0.32	0.00	-0.71	-0.60	-0.45	-0.60
1965								
1966								
1967								
1968								
1969								
1970								
1971								
1972								
1973								
1974	0.18	-0.11	-0.15	[illegible]	-0.06	-0.31	-0.54	-0.41
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984					-0.82	-0.68	-0.55	
1985								
1986								
1987								
1988								
1989								
1990	0.13	0.77	0.15	0.97	0.84	0.31	0.34	0.10
1991	0.13	0.77	0.15	0.97	0.84	0.31	0.34	0.10
1992	0.51	[illegible]	[illegible]	[illegible]	[illegible]	0.00	-0.01	[illegible]
1993	3.01	3.31	2.87	2.91	0.34	[illegible]	0.00	[illegible]
1994	0.46	0.09	0.70	-0.24	[illegible]	-0.04	0.75	-0.35
1995	-0.39	0.83	[illegible]	0.00	[illegible]	1.47	0.79	[illegible]
1996	-2.09	0.78	-0.13	[illegible]	0.21	0.41	-0.47	
1997	-2.51	[illegible]	[illegible]	0.22	-0.27			
1998	-0.47	0.87	[illegible]	0.86	-0.37	0.62	[illegible]	[illegible]
1999	0.91	[illegible]	0.79	[illegible]	3.07	2.43	[illegible]	[illegible]
2000	[illegible]	0.87	[illegible]	0.08	0.58	[illegible]	[illegible]	0.29
2001	[illegible]	0.01	[illegible]	[illegible]	[illegible]	[illegible]	0.75	0.38
2002	[illegible]	-2.28		0.97		-0.26	0.42	
2003	-2.03	[illegible]	-2.48	-1.52	[illegible]	[illegible]	2.56	2.44
2004	[illegible]	[illegible]	-2.95	0.10	2.70	2.34	4.47	2.94
2005	-0.54	[illegible]	0.73	1.00	2.24	2.56	0.42	0.39
2006	[illegible]	[illegible]	-0.37	0.04	[illegible]	3.31	2.07	2.65

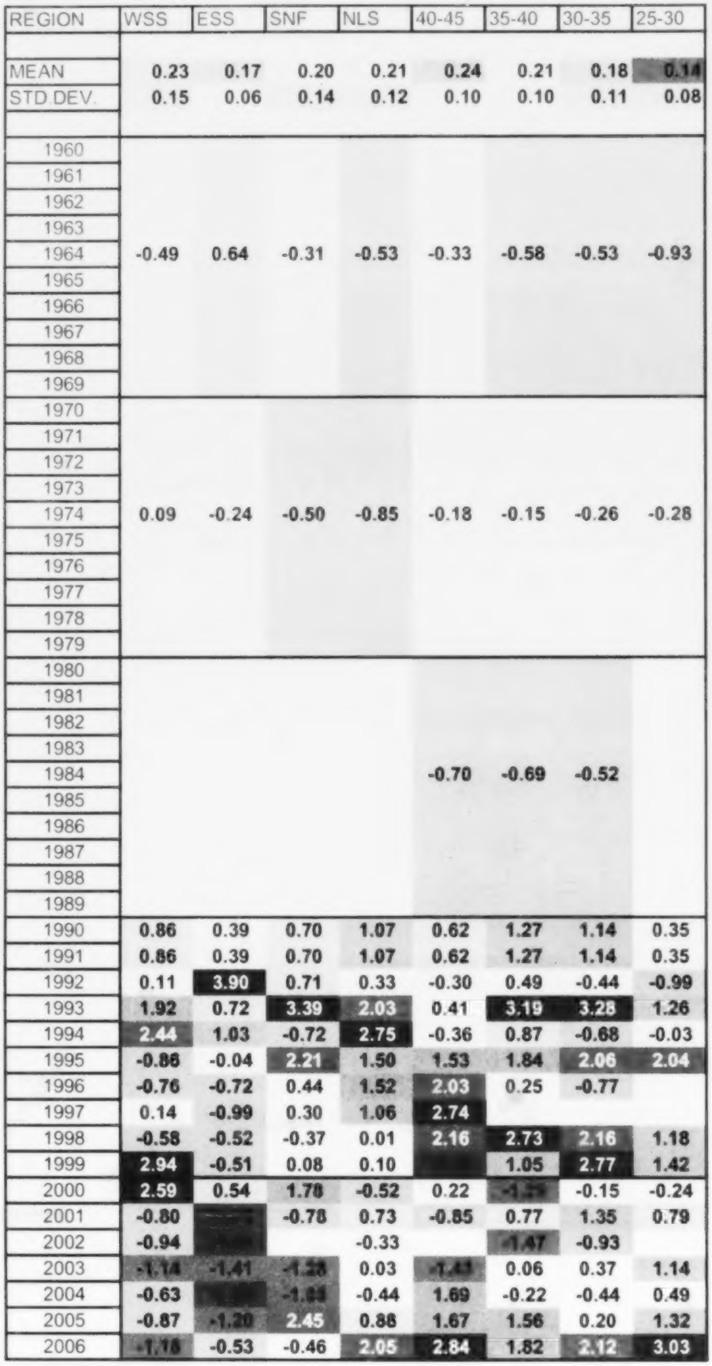
REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.34	[illegible]	[illegible]	0.36	0.69	0.65	0.61	0.51
STD.DEV.	0.22	0.10	0.07	0.18	0.30	0.23	0.22	0.20
1990	0.25	0.08	-0.42	-0.43	-0.27	-0.54	[illegible]	-0.46
1991	0.25	0.08	-0.42	-0.43	-0.27	-0.54	[illegible]	-0.46
1992	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-2.15	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.71
1994	-0.44	-0.38	-0.15	[illegible]	0.23	0.03	[illegible]	-0.02
1995	[illegible]	[illegible]	0.24	0.35	[illegible]	-0.23	0.74	[illegible]
1996	[illegible]	[illegible]	[illegible]	[illegible]	0.11	0.70	0.57	
1997	[illegible]	-0.43	[illegible]	[illegible]	[illegible]			
1998	[illegible]	[illegible]	0.97	0.15	0.50	0.63	[illegible]	[illegible]
1999	[illegible]	2.12	[illegible]	[illegible]	[illegible]	0.92	0.10	-0.03
2000	[illegible]	[illegible]	[illegible]	0.14	-0.34	[illegible]	[illegible]	[illegible]
2001	[illegible]	-0.44	0.55	[illegible]	-0.02	0.77	0.46	-0.14
2002	[illegible]	0.14		-0.11		[illegible]	[illegible]	
2003	[illegible]	[illegible]	-0.50	0.09	[illegible]	[illegible]	0.20	[illegible]
2004	[illegible]	[illegible]	-0.41	0.80	-0.28	0.18	0.31	-0.04
2005	[illegible]	-0.43	[illegible]	-0.54	[illegible]	[illegible]	[illegible]	[illegible]
2006	-0.20	-0.18	0.29	[illegible]	2.48	2.21	[illegible]	[illegible]

Fig. 6. Standardised abundance anomalies for small copepods (*Paracalanus/Pseudocalanus*, left hand column) and foramnifera (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



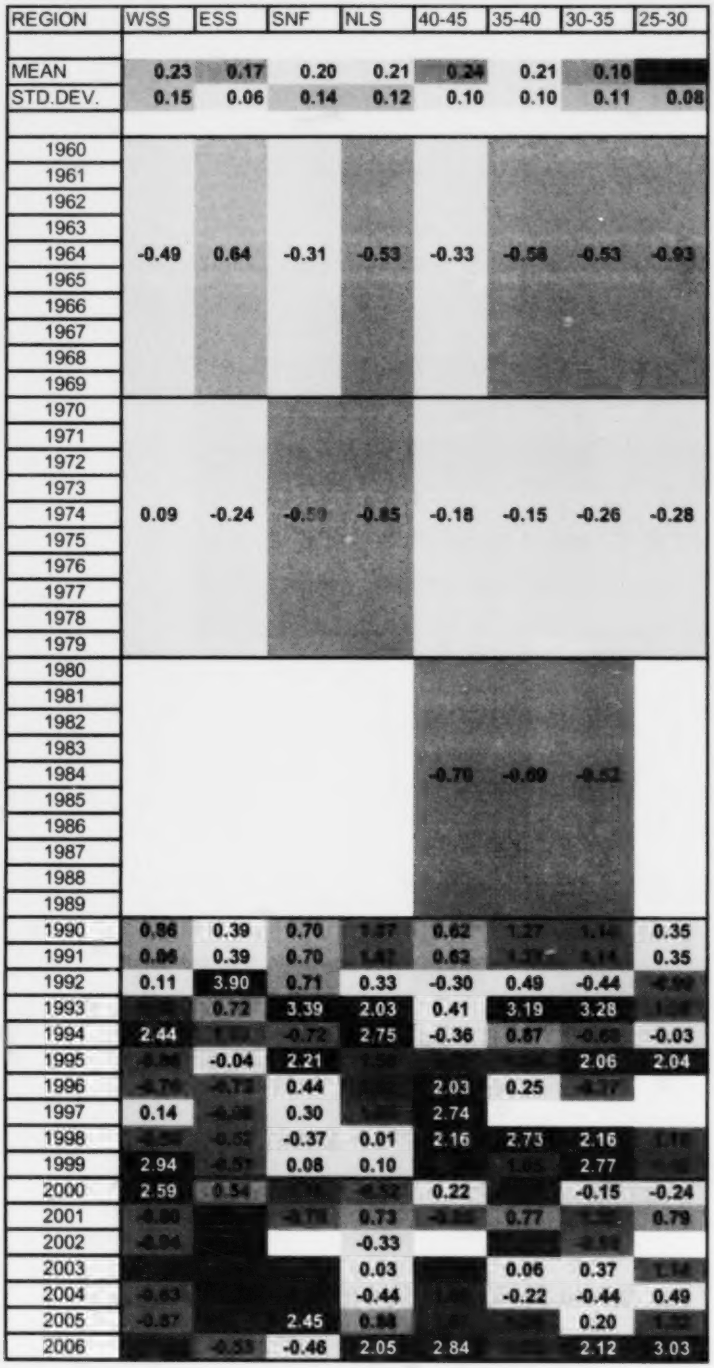
REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.40	[illegible]	[illegible]	0.34	0.53	0.48	0.40	0.39	0.10	[illegible]	0.10	0.29	[illegible]	0.20	0.18	0.19
STD.DEV.	0.11	0.06	0.11	0.08	0.08	0.08	0.06	0.07	0.04	0.02	0.04	0.06	0.09	0.07	0.05	0.04
1960	0.38	0.44	-0.48	0.15	1.08	0.02	-0.46	-0.11	-0.80	-0.44	[illegible]	-0.37	-0.40	0.13	-0.26	-0.01
1961																
1962																
1963																
1964																
1965																
1966																
1967																
1968																
1969																
1970	1.24	0.72	1.49	0.95	-0.22	-0.15	0.01	-0.89	-0.56	-0.41	-0.03	0.05	-0.89	-0.86	-0.81	[illegible]
1971																
1972																
1973																
1974																
1975																
1976																
1977																
1978																
1979																
1980					-0.25	0.04	-0.19						-0.39	-0.78	-0.46	
1981																
1982																
1983																
1984																
1985																
1986																
1987																
1988																
1989																
1990	-0.65	[illegible]	-0.82	-0.12	0.46	0.91	0.89	[illegible]	0.70	0.72	1.11	[illegible]	[illegible]	1.26	0.67	0.38
1991	[illegible]	[illegible]	-0.62	-0.12	0.46	0.91	0.89	[illegible]	0.70	0.72	[illegible]	[illegible]	[illegible]	[illegible]	0.67	0.38
1992	-0.06	-0.27	[illegible]	-0.36	[illegible]	1.26	1.31	[illegible]	0.48	-0.61	0.41	0.77	-0.32	0.57	3.16	0.75
1993	[illegible]	0.33	-0.10	[illegible]	0.83	[illegible]	2.08	[illegible]	[illegible]	0.84	0.84	0.50	[illegible]	2.37	0.46	-0.05
1994	[illegible]	-0.42	0.44	-0.18	0.25	[illegible]	-0.34	[illegible]	[illegible]	[illegible]	2.70	0.93	0.77	0.57	[illegible]	0.17
1995	[illegible]	[illegible]	-0.29	2.94	2.58	2.72	3.28	0.96	-0.87	0.15	0.50	2.57	3.26	2.03	[illegible]	[illegible]
1996	-0.96	-2.17	[illegible]	-0.72	-0.78	[illegible]	-0.81		2.16	[illegible]	[illegible]	2.90	2.41	[illegible]	[illegible]	
1997	[illegible]	-2.49	[illegible]	-0.77	0.58				2.21	1.15	[illegible]	[illegible]	0.46			
1998	-0.61	[illegible]	-0.64	-0.40	[illegible]	[illegible]	[illegible]	-0.49	[illegible]	0.56	[illegible]	-0.11	0.73	[illegible]	-0.18	-0.03
1999	-1.70	0.46	[illegible]	[illegible]	-3.18	[illegible]	-2.71	-0.06	-0.03	3.20	0.85	[illegible]	0.22	1.07	[illegible]	[illegible]
2000	-0.41	[illegible]	-0.24	[illegible]	-2.13	[illegible]	-0.43	[illegible]	0.98	[illegible]	0.76	[illegible]	2.74	[illegible]	[illegible]	2.16
2001	[illegible]	-0.40	[illegible]	[illegible]	[illegible]	-0.33	0.48	[illegible]	0.28	0.02	0.35	0.02	[illegible]	0.50	0.86	-0.01
2002	-1.69	-1.95		-0.79		-3.70	2.86		-0.06	[illegible]		0.26		[illegible]	[illegible]	
2003	-0.21	0.43	[illegible]	[illegible]	[illegible]	0.17	0.81	-0.75	0.04	0.50	-0.50	[illegible]	-2.10	-0.01	1.20	[illegible]
2004	[illegible]	[illegible]	[illegible]	0.03	-0.71	[illegible]	[illegible]	-0.49	3.05	3.63	0.39	-0.42	0.41	-0.01	[illegible]	0.70
2005	[illegible]	0.32	-0.23	[illegible]	[illegible]	[illegible]	[illegible]	2.66	0.27	-0.78	-0.26	[illegible]	0.58	2.28	2.19	0.37
2006	-0.85	[illegible]	-0.08	[illegible]	-0.38	[illegible]	0.45	0.26	[illegible]	-0.04	[illegible]	[illegible]	0.91	0.92	[illegible]	3.06

Fig. 7. Standardised abundance anomalies for euphausiids (left hand column) and hyperiids (right hand column) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



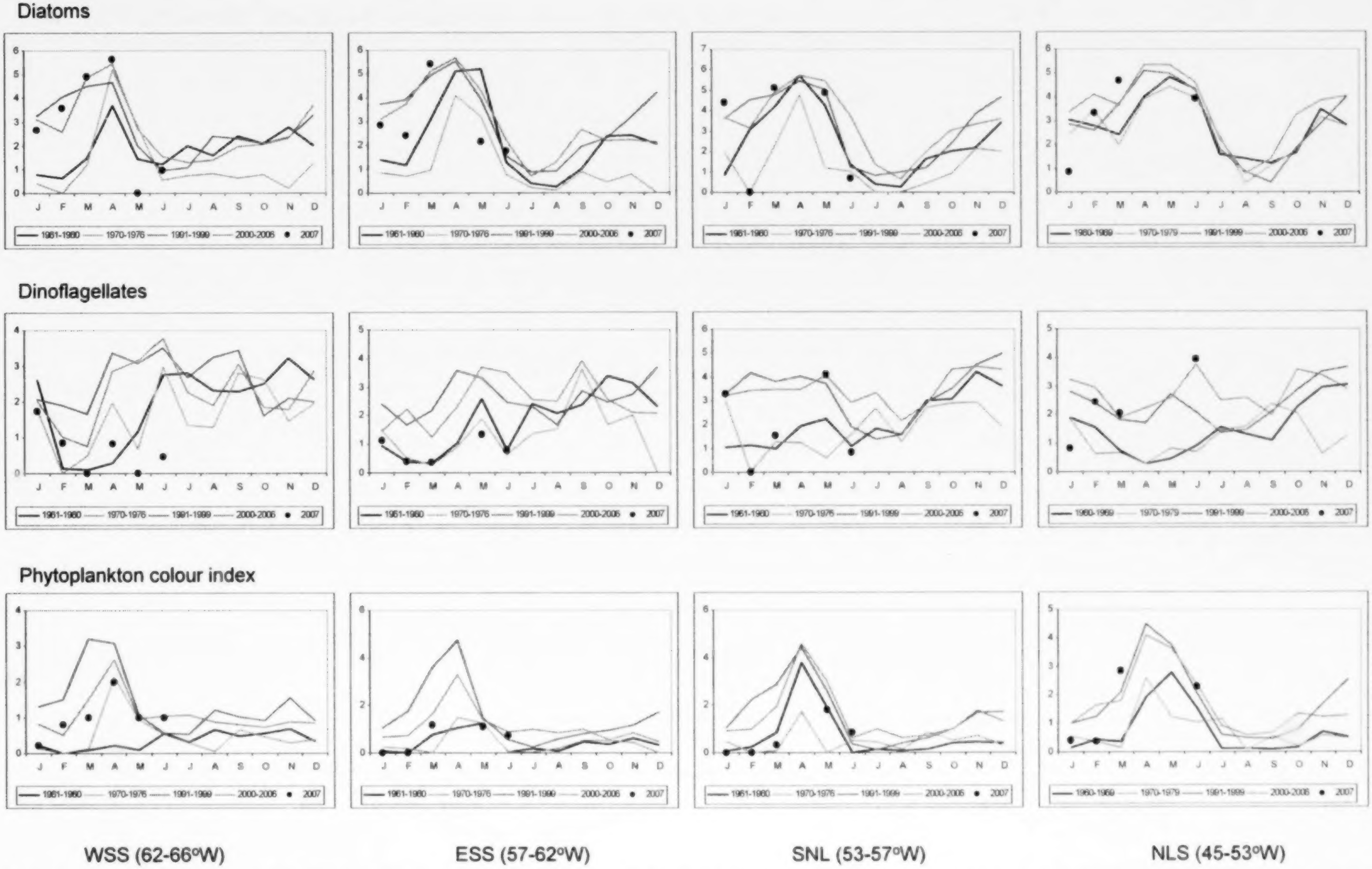
REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.23	0.17	0.20	0.21	0.24	0.21	0.18	0.14
STD.DEV.	0.15	0.06	0.14	0.12	0.10	0.10	0.11	0.08
1960	-0.49	0.64	-0.31	-0.53	-0.33	-0.58	-0.53	-0.93
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	0.09	-0.24	-0.50	-0.85	-0.18	-0.15	-0.26	-0.28
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.70	-0.69	-0.52	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	0.86	0.39	0.70	1.07	0.62	1.27	1.14	0.35
1991	0.86	0.39	0.70	1.07	0.62	1.27	1.14	0.35
1992	0.11	3.90	0.71	0.33	-0.30	0.49	-0.44	-0.99
1993	1.92	0.72	3.39	2.03	0.41	3.19	3.28	1.26
1994	2.44	1.03	-0.72	2.75	-0.36	0.87	-0.68	-0.03
1995	-0.86	-0.04	2.21	1.50	1.53	1.84	2.06	2.04
1996	-0.76	-0.72	0.44	1.52	2.03	0.25	-0.77	
1997	0.14	-0.99	0.30	1.06	2.74			
1998	-0.58	-0.52	-0.37	0.01	2.16	2.73	2.16	1.18
1999	2.94	-0.51	0.08	0.10	[illegible]	1.05	2.77	1.42
2000	2.59	0.54	1.78	-0.52	0.22	[illegible]	-0.15	-0.24
2001	-0.80	[illegible]	-0.78	0.73	-0.85	0.77	1.35	0.79
2002	-0.94	[illegible]		-0.33		-1.47	-0.93	
2003	-1.14	-1.41	-1.28	0.03	[illegible]	0.06	0.37	1.14
2004	-0.63	[illegible]	[illegible]	-0.44	1.69	-0.22	-0.44	0.49
2005	-0.87	-1.20	2.45	0.88	1.67	1.56	0.20	1.32
2006	-1.16	-0.53	-0.46	2.05	2.84	1.82	2.12	3.03

Fig. 8. Standardised abundance anomalies for *Limacina* (a pteropod) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



REGION	WSS	ESS	SNF	NLS	40-45	35-40	30-35	25-30
MEAN	0.23	0.17	0.20	0.21	0.24	0.21	0.10	[illegible]
STD.DEV.	0.15	0.06	0.14	0.12	0.10	0.10	0.11	0.08
1960	-0.49	0.64	-0.31	-0.53	-0.33	-0.58	-0.53	-0.93
1961								
1962								
1963								
1964								
1965								
1966								
1967								
1968								
1969								
1970	0.09	-0.24	-0.59	-0.85	-0.18	-0.15	-0.26	-0.28
1971								
1972								
1973								
1974								
1975								
1976								
1977								
1978								
1979								
1980					-0.70	-0.69	-0.52	
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990	0.86	0.39	0.70	1.37	0.62	1.27	1.14	0.35
1991	0.86	0.39	0.70	1.47	0.63	1.37	1.14	0.35
1992	0.11	3.90	0.71	0.33	-0.30	0.49	-0.44	[illegible]
1993	[illegible]	0.72	3.39	2.03	0.41	3.19	3.28	[illegible]
1994	2.44	[illegible]	-0.72	2.75	-0.36	0.87	[illegible]	-0.03
1995	[illegible]	-0.04	2.21	[illegible]	[illegible]	[illegible]	2.06	2.04
1996	-0.76	-0.72	0.44	[illegible]	2.03	0.25	-0.77	
1997	0.14	[illegible]	0.30	[illegible]	2.74			
1998	[illegible]	-0.52	-0.37	0.01	2.16	2.73	2.16	[illegible]
1999	2.94	-0.57	0.08	0.10	[illegible]	1.05	2.77	[illegible]
2000	2.59	0.54	[illegible]	-0.52	0.22	[illegible]	-0.15	-0.24
2001	-0.80	[illegible]	-0.78	0.73	[illegible]	0.77	[illegible]	0.79
2002	-0.94	[illegible]		-0.33		[illegible]	[illegible]	
2003	[illegible]	[illegible]	[illegible]	0.03	[illegible]	0.06	0.37	1.14
2004	-0.63	[illegible]	[illegible]	-0.44	[illegible]	-0.22	-0.44	0.49
2005	-0.87	[illegible]	2.45	0.88	[illegible]	[illegible]	0.20	1.32
2006	[illegible]	-0.55	-0.46	2.05	2.84	[illegible]	2.12	3.03

Fig. 8. Standardised abundance anomalies for *Limacina* (a pteropod) from the 1960s to 2006. Long-term means are standardised to the value of the maximum long-term mean. The standard deviations are colour coded by standardising as a percentage of the mean. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.



Diatoms

Dinoflagellates

Phytoplankton colour index

WSS (62-66°W) ESS (57-62°W) SNL (53-57°W) NLS (45-53°W)

Fig. 9. Seasonal cycles of diatom (upper row) and dinoflagellate (middle row) abundance and the phytoplankton colour index (lower row) by decade and with data for the months sampled in 2007 west of 45°W. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

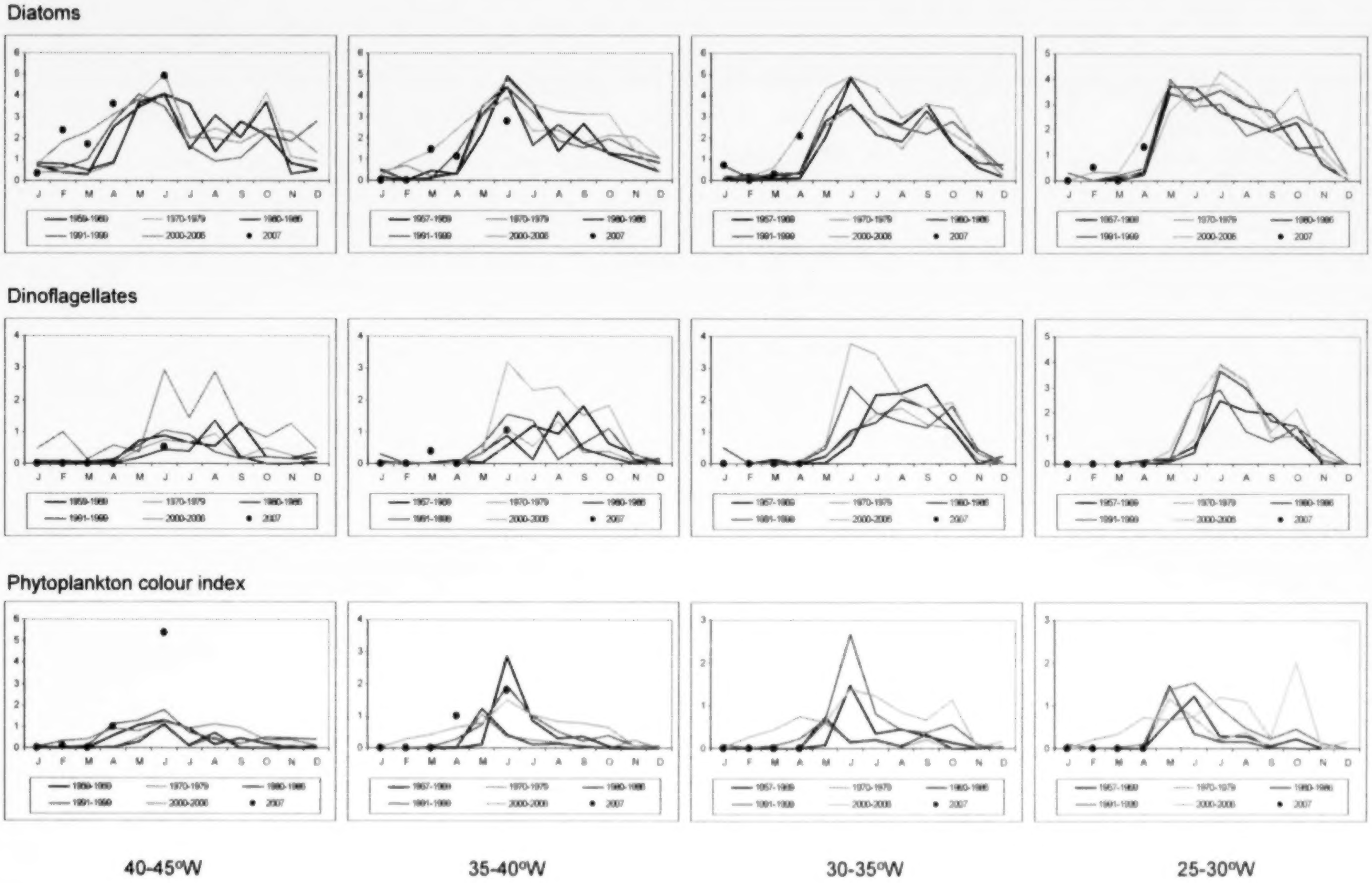


Fig. 10. Seasonal cycles of diatom (upper row) and dinoflagellate (middle row) abundance and the phytoplankton colour index (lower row) by decade and with data for the months sampled in 2007 east of 45°W.

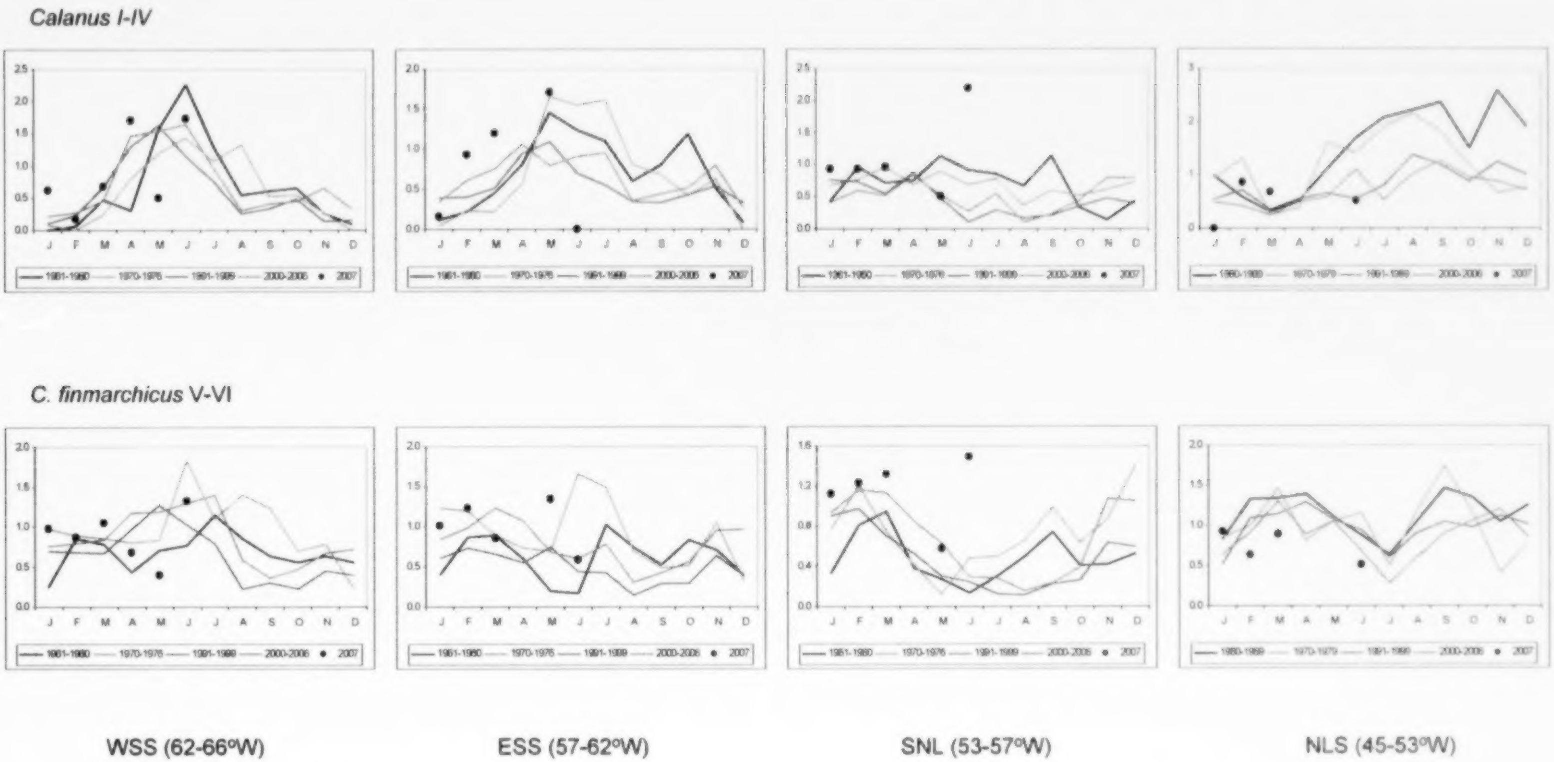
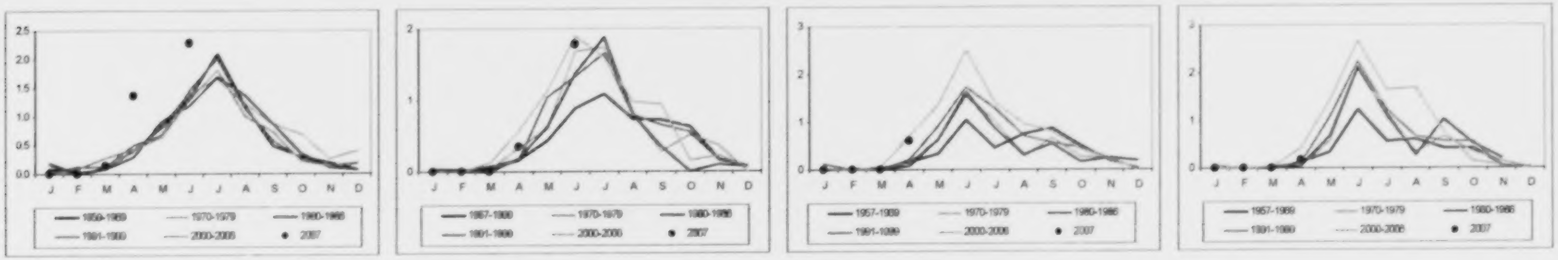
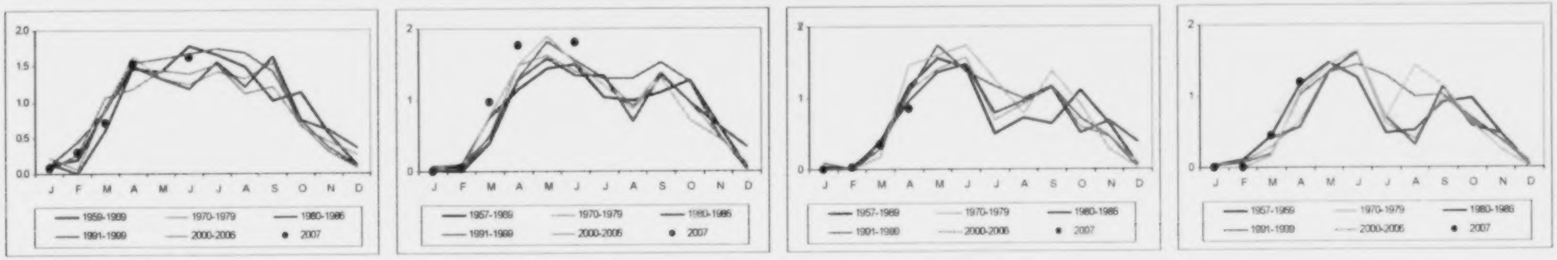


Fig. 11. Seasonal cycles of abundance of *Calanus* I-IV (upper row, mostly *Calanus finmarchicus*) and *Calanus finmarchicus* V-VI (lower row) by decade and with data for the months sampled in 2007 west of 45°W. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

Calanus I-IV



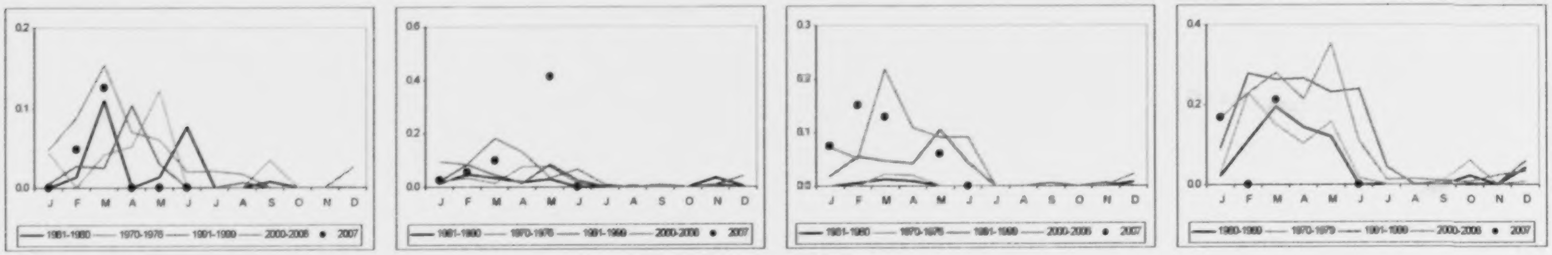
C. finmarchicus V-VI



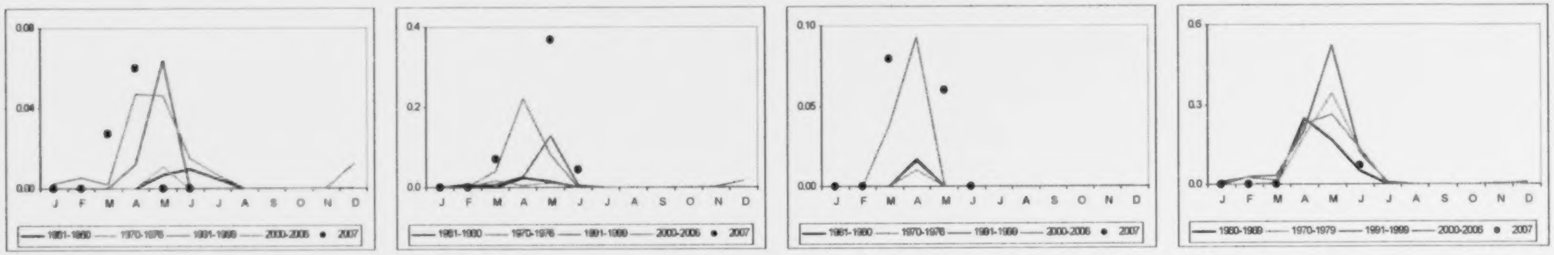
40-45°W 35-40°W 30-35W 25-30°W

Fig. 12. Seasonal cycles of abundance of *Calanus* I-IV (upper row, mostly *Calanus finmarchicus*) and *Calanus finmarchicus* V-VI (lower row) by decade and with data for the months sampled in 2007 east of 45°W.

Calanus glacialis



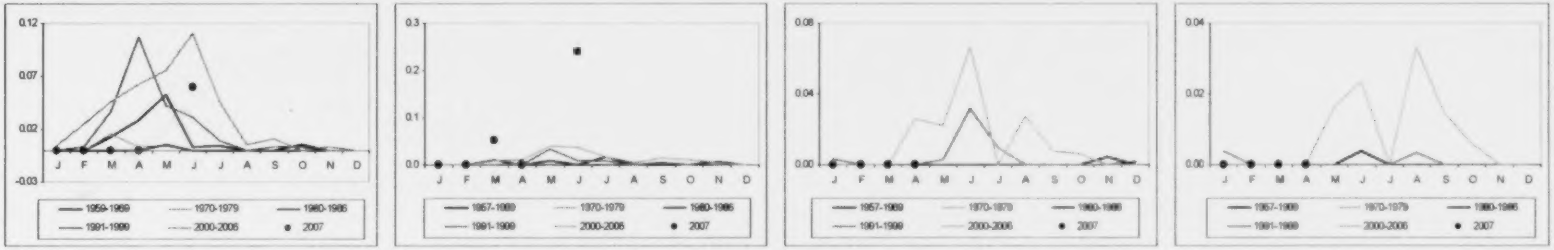
Calanus hyperboreus



WSS (62-66°W) ESS (57-62°W) SNL (53-57°W) NLS (45-53°W)

Fig. 13. Seasonal cycles of abundance of *Calanus glacialis* V-VI (upper row) and *Calanus hyperboreus* III-VI (lower row) by decade and with data for the months sampled in 2007 west of 45°W. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

Calanus glacialis



Calanus hyperboreus

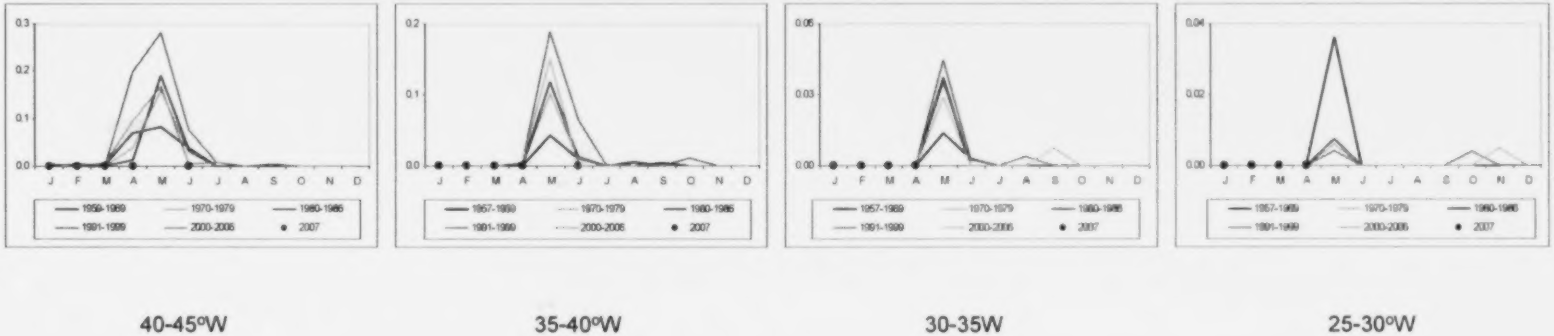
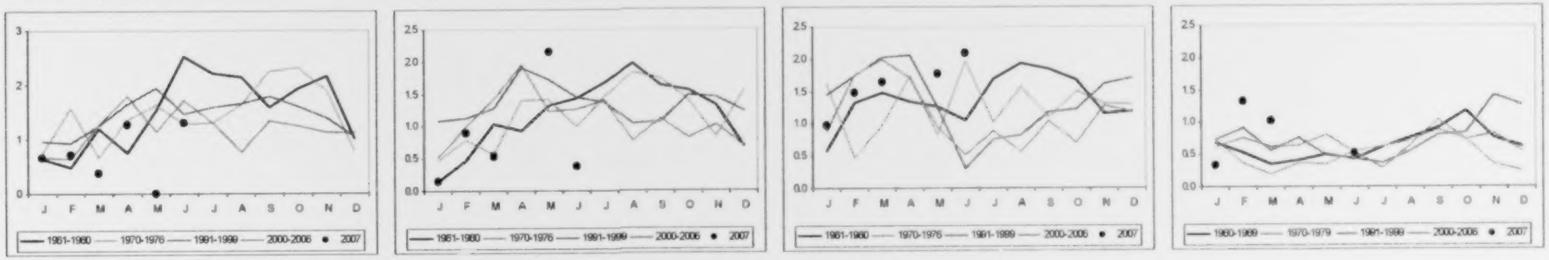


Fig. 14. Seasonal cycles of abundance of *Calanus glacialis* V-VI (upper row) and *Calanus hyperboreus* III-VI (lower row) by decade and with data for the months sampled in 2007 east of 45°W.

Small copepods



Foramnifera

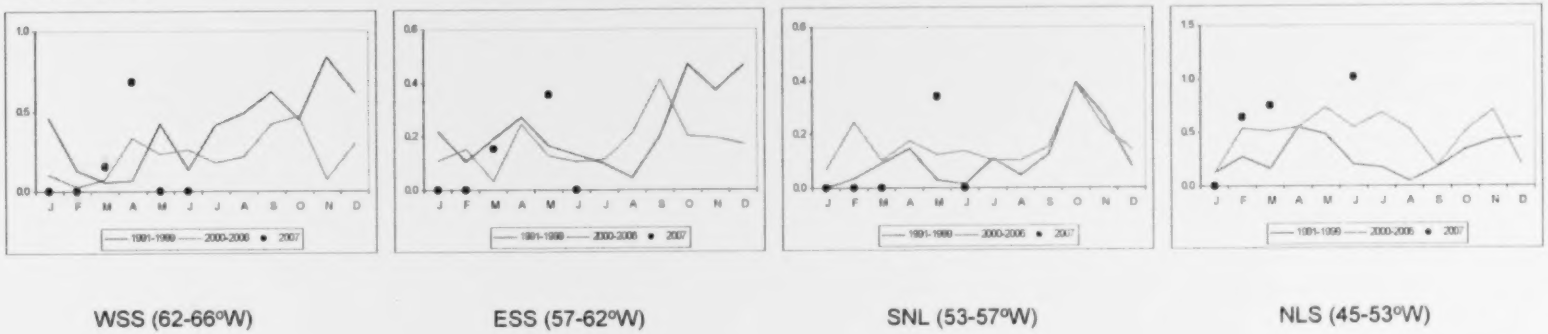
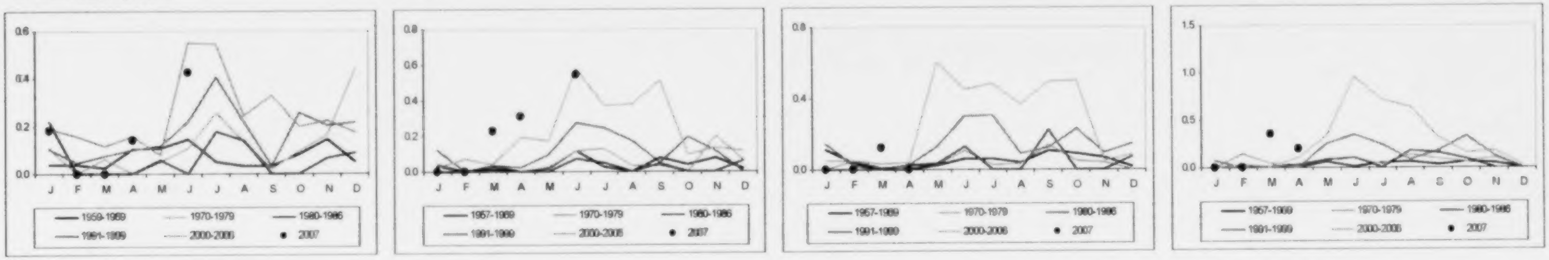
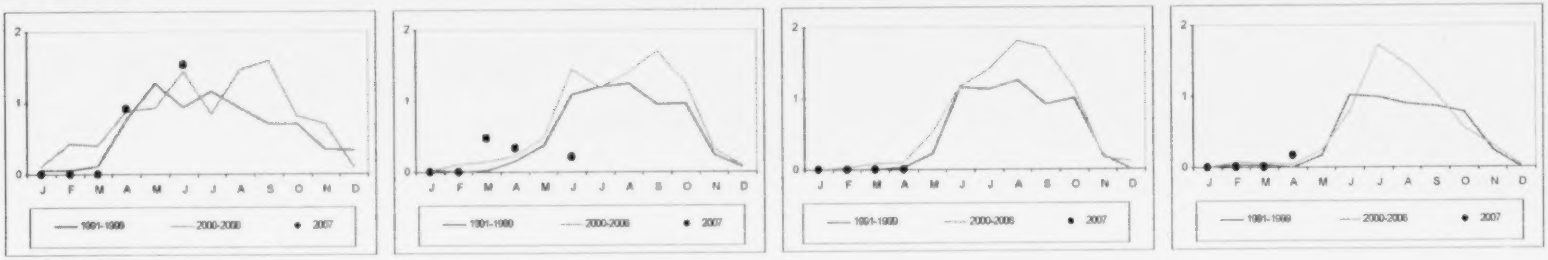


Fig. 15. Seasonal cycles of abundance of small copepods (the *Paracalanus/Pseudocalanus* category, upper row) and copepod nauplii (only counted since 1992, lower row) by decade and with data for the months sampled in 2007 west of 45°W. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

Small copepods



Foramnifera



40-45°W 35-40°W 30-35°W 25-30°W

Fig. 16. Seasonal cycles of abundance of small copepods (the *Paracalanus/Pseudocalanus* category, upper row) and copepod nauplii (only counted since 1992, lower row) by decade and with data for the months sampled in 2007 east of 45°W.

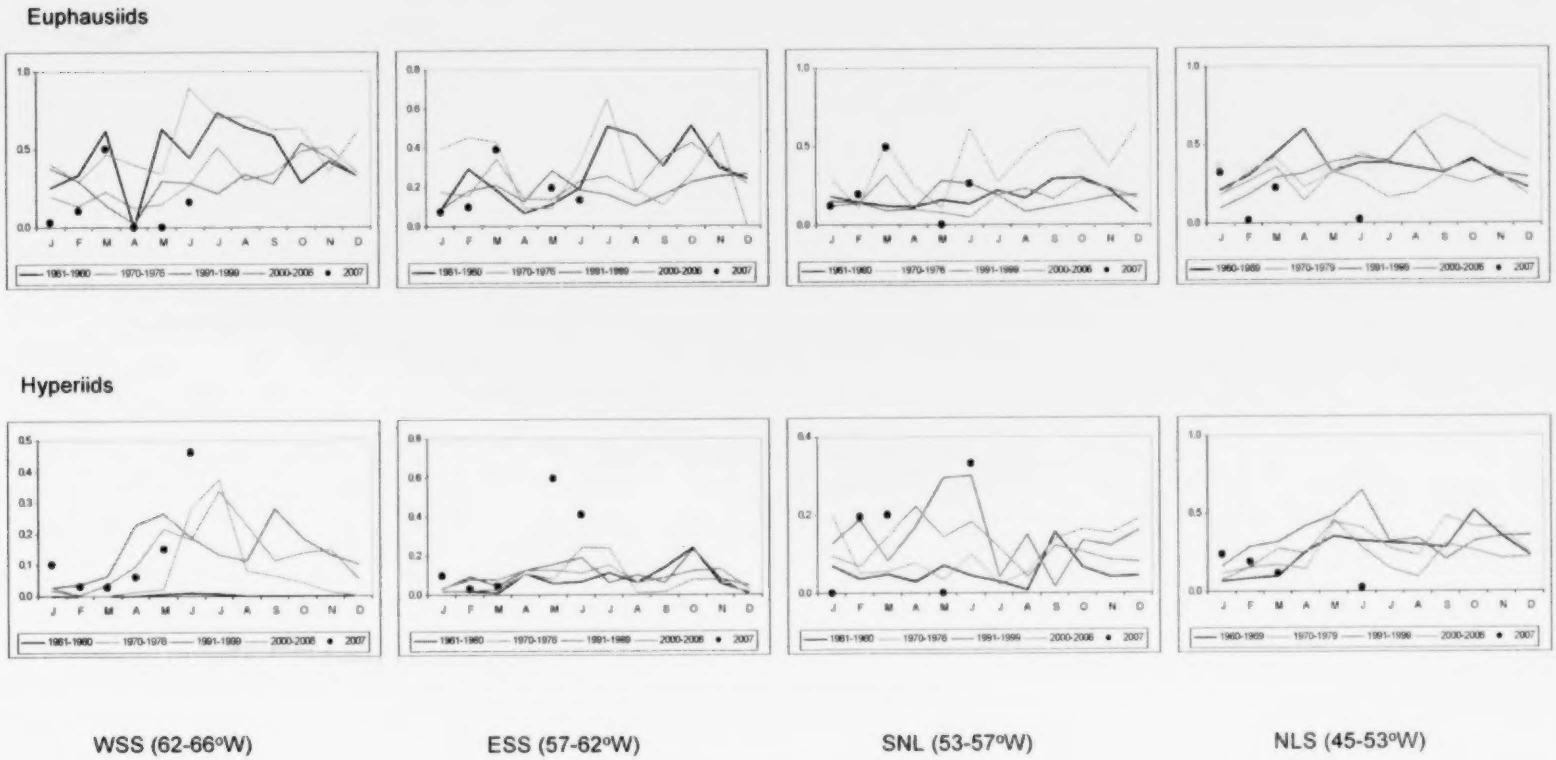
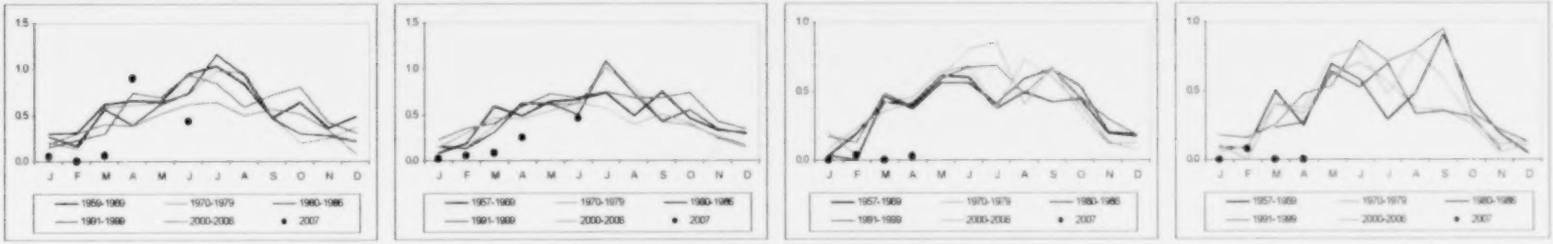
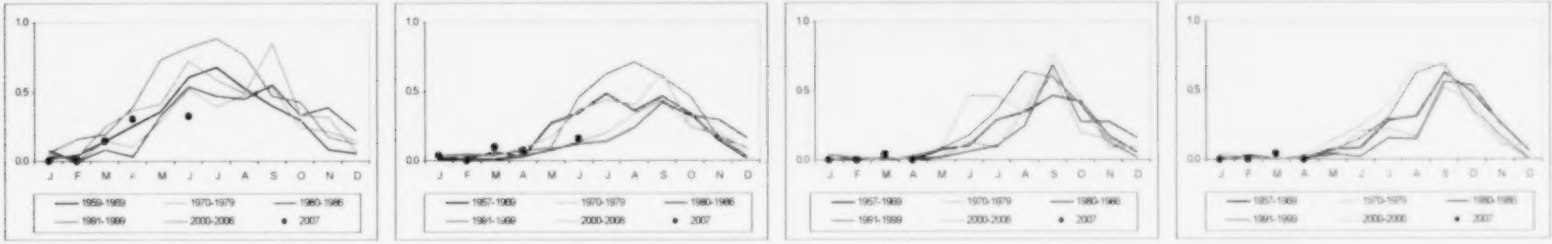


Fig. 17. Seasonal cycles of abundance of euphausiids (upper row) and hyperiids (amphipods, lower row) by decade and with data for the months samples in 2007 west of 45°W. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.

Euphausiids



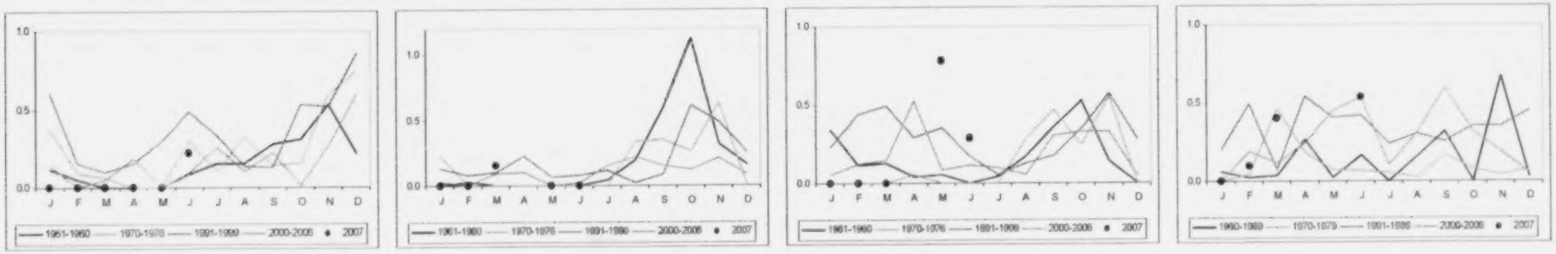
Hyperiids



40-45°W 35-40°W 30-35°W 25-30°W

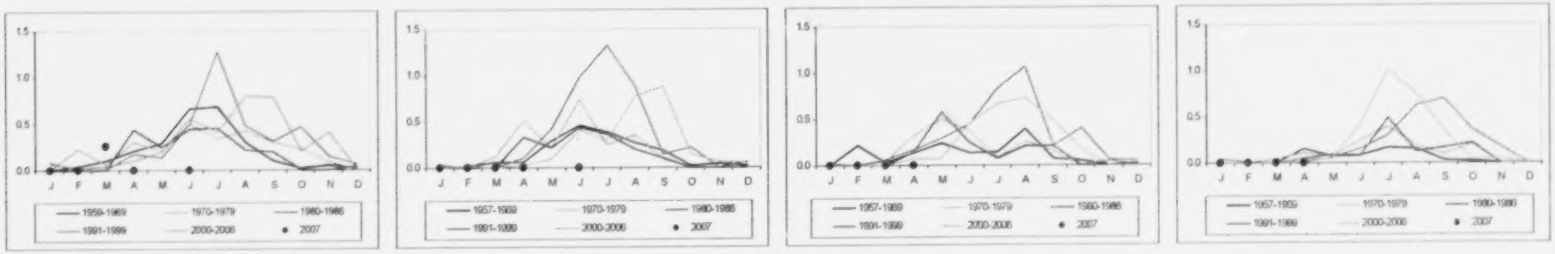
Fig. 18. Seasonal cycles of abundance of euphausiids (upper row) and hyperiids (amphipods, lower row) by decade and with data for the months samples in 2007 east of 45°W.

West of 45°W



WSS (62-66°W) ESS (57-62°W) SNL (53-57°W) NLS (45-53°W)

East of 45°W



40-45°W 35-40°W 30-35°W 25-30°W

Fig. 19. Seasonal cycles of abundance of *Limacina*, a genus of pteropod with a shell made of calcium carbonate, by decade and with data for the months samples in 2007. WSS = Western Scotian Shelf, ESS = Eastern Scotian Shelf, SNL = South Newfoundland (shelf), NLS = Newfoundland Shelf.